Discovering how scientific literacy has been positioned in the new *Australian Curriculum: Science*

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Statement of Original Authorship

"The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made."

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Keywords

Scientific literacy, Australian Curriculum, Critical Discourse Analysis. Science education, Multiliteracies, New Learning, linguistic position

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ABSTRACT

Much research has indicated the imperative to develop scientifically literate students, ensuring they are able to construct and deconstruct text. However, for too long Science curriculum documents have linguistically prioritised the transmission of scientific content and knowledge. This thesis investigated the perceived importance of scientific literacy in the new *Australian Curriculum: Science*, a document which aims to provide all Australian students with opportunities to develop deep understandings about the importance of science and how to contribute scientifically to society, with the anticipation that students become 'scientifically literate'. Through the use of critical discourse analysis, the position of scientific literacy within this new curriculum was revealed as ambiguous, and the document did not seem to provide a detailed scope for intentional teaching for scientific literacy. To overcome this problem of ambiguity regarding scientific literacy, recommendations on how to intentionally teach for scientific literacy within the implementation of the *Australian Curriculum: Science* were provided. These findings may contribute to future decisions by Australian Science teachers about how to implement the new *Australian Curriculum: Science* with a focus on improving scientific literacy outcomes for all Australian Science students.

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Chapter 1: INTRODUCTION

This research investigation was born out of the response I received from my Science class one day when I told them not to trust me as a Science teacher, to question everything I said, and that Science teachers didn't know everything. They were stunned by my statement. One student stated that since their first day in science, they had always assumed Science teachers knew everything and that the teacher couldn't be challenged. In addition, this student proclaimed that scientists were to be completely trusted, and that every new discovery presented by scientists to society was to be heralded as fact. I was surprised by the student's apparent lack of scientific literacy, their unwillingness to analyse critically the scientific information provided, and their inability to recognise the impact that society and science have on each other. As Science Head of Department, it was my job to ensure the development of scientific literacy by all our students, not just the ones in my Science classes. Moreover, this development of scientific literacy should be through good curriculum and pedagogy development. If the development of scientifically literate students was to be the focus of the Science department for the foreseeable future, then I needed to understand scientific literacy in all its forms, and successful methods of incorporating it into our future Australian Curriculum. I wanted to base it on evidence, and not have it as a 'bolt-on' to what was a content-full curriculum. Therefore, this research investigation was born.

This investigation will discover the linguistic position of scientific literacy in the new *Australian Curriculum: Science* by examining how the language of the document demonstrates its importance to science education. Section 1.1 provides background information on why intentional teaching for scientific literacy is critical to Science education. This is followed by the definition of scientific literacy in Section 1.2. A summary of the research aims and questions can be found in Section

1.3, with the scope of the research outlined in Section 1.4. The research design is explained in Section 1.5, with the expected outcomes of this research described in Section 1.6. Section 1.7 explains the significance of this investigation, and Section 1.8 concludes Chapter 1 with a summary.

1.1 Background

The teaching of English language literacy in secondary schools has long been seen as the domain of the English teacher, and not part of a Science teacher's role (Alvermann, Rezak, Mallozzi, Boatright & Jackson, 2011; Hanrahan, 2009). Secondary Science is often viewed as a 'hands-on' subject, and according to Alvermann, et al. (2011), Hanrahan (2009) and Fang & Wei (2010), Science teachers see their subject as containing little need for English language literacy, and therefore do not allocate time for literacy instruction in their classrooms. In fact, many Science teachers can be hesitant to attempt the intentional teaching of literacy, as they do not see themselves as language teachers (Yore & Treagust, 2006), or find difficulties when attempting to incorporate literacy strategies, such as teaching text structure, approaches for reading aloud and concept mapping, into Science lessons (Fang & Wei, 2010). This is due to Science teachers potentially misinterpreting literacy as the study of language, text and the written word. They may understand literacy to be grammatical conventions, paragraph structure and spelling, and therefore the responsibility of the English teacher (Hanrahan, 2009). In this investigation however, an exploration into the nature of scientific literacy, which encompasses more than the study of text on a page, will be undertaken.

The nature of science requires that students are able to comprehend a variety of language conventions, text types and modalities. Fang & Wei (2010) explain how scientists use structured language conventions to describe techniques, and explain and justify theories. Norris & Phillips (2003) state that even though scientific theories are not dependent on specific types of text (as theories can be presented in many different formats), science cannot exist without text itself. The expectation that students can understand the scientific content embedded within these different modes of science texts and language constructs, without intentional teaching for scientific literacy and comprehension, can often lead to poor understanding of the content material (Fang & Wei, 2010; Zywica & Gomez, 2008). Therefore, a demand could be placed on Science teachers to understand the nature of scientific literacy and intentionally teach for it in their classrooms (Liu, 2009; Yore & Treagust, 2006). This 'intentional teaching' for scientific literacy can be defined as providing step-by-step instruction for students to understand how the texts they encounter (including traditional and multimodal text types) have been constructed, influenced by the author, the field and broader society, and presented to the reader. This type of understanding may not be gleaned from traditional content-driven Science lessons. To develop scientific literacy in their students, teachers should explain its nature, provide examples of text types, actively promote critical analysis of what has been presented, and encourage all students to engage with texts to discover how they fit within the ways of knowing and doing in contemporary science.

For Science students to be proficient consumers and producers of science texts, they should be able to grasp meanings, clarify theories and evaluate ideas. To achieve this, they may need a variety of processes and strategies, which Science educators can sometimes presume students already have. Some Science teachers may show little interest in teaching their students to read and comprehend text at any level, and therefore subconsciously reinforce the view that literacy is not a part of Science learning (Norris & Phillips, 2003).

In fact, many Science teachers may be overlooking a key aspect of teaching Science if they fail to recognise the importance of scientific literacy in their Science instruction. As stated by Norris & Phillips (2003, p. 237):

> *The claim to know some scientific statement is a claim to know the process or likely process through which the statement was conceived, the degree of certainty that the field attaches to the statement, the role in reasoning the statement plays in connection with other scientific statements, and the implications of the statement's being true. If such interrelationships are missed in the reading, then the point of science is missed. The main source of both the substantive content of science and of the interrelationship within it is accurate interpretation of science text.*

Much research has indicated the imperative to develop scientifically literate students, including the construction and deconstruction of scientific texts (Anthony, Tippett, & Yore, 2010). It is suggested that a bridge be built over the gap between Science education and literacy practices in Science classrooms (Fang & Wei, 2010). In response to this, there have been many opportunities for curriculum reform, including studies into how both Science students and Science teachers see their scientific knowledge and literacy (Pouliot, Bader, & Therriault, 2010). However, this investigation proposes that more work is required in relation to the practicalities of incorporating targeted scientific literacy activities into the Science curriculum, to provide Science teachers with a solid foundation for intentionally teaching for scientific literacy.

Rennie and Goodrum (2007) describe how issues within some Science education systems are due to the nature of the curriculum itself, which has historically been scientific content heavy and could hamper the efforts of teachers to provide engaging Science education classrooms. Some Science teachers may hold the view that school Science curricula should emphasise basic knowledge, facts, procedures and processes of science first, and only if time permits could there be the sideline opportunity to make links to social issues and scientific literacy (Bybee, 2009). Therefore, although curriculum reform may be necessary to remove some content and incorporate intentional teaching for scientific literacy in the classroom, there could also be a paradigm shift in the pedagogical practices of Science teachers. They could 'let go' of their need to didactically disseminate abstract scientific content, and embrace intentional teaching for scientific literacy and the incorporation of socio-scientific issues into the core of their Science teaching, where the nature of science can be investigated in a social setting, and how it interacts with areas such as politics and economics (Holbrook, 2010; Holbrook & Rannikmae, 2009; Yore, Hand, Goldman, & Hildebrand, 2004).

Based on this need for a paradigm shift in Science education, this investigation aims to discover the nature of scientific literacy and its many definitions and perspectives in the current literature. From these definitions and perspectives, a set of key elements for developing scientific literacy is proposed, to detail what intentional teaching for scientific literacy could include. These elements are used to conduct a critical discourse analysis of the new *Australian Curriculum: Science* to identify how scientific literacy is represented in this document. This thesis concludes with recommendations for Science teachers about how to incorporate intentional teaching for scientific literacy into the implementation of the new *Australian Curriculum: Science*.

1.2 Defining Scientific Literacy

The first use of the term 'scientific literacy' was by Paul deHard Hurd in 1958 (Holbrook & Rannikmae, 2009). However, deHard Hurd and other individuals first advocating for an understanding of scientific literacy never provided a clear definition of what the term meant (Dillon, 2009; Laugksch, 2000), and there is still no universally accepted definition (DeBoer, 2000; Millar, 2006). Due to this lack of clarity, some have called for the term to be removed from Science education, and that this should no longer be a goal for all students (Holbrook & Rannikmae, 2009). Nevertheless, scientific literacy has become increasing popular in discussions about Science education, it still underpins many of the current standards of Science curricula around the world, and is at the core of major international assessments used to compare student achievement (Dillon, 2009; Millar, 2006).

An in-depth history of the term 'scientific literacy' was outlined by DeBoer in his paper *"Scientific Literacy: Another look at its historical and contemporary meanings and its relationship to science education reform"* (2000). This paper started with a recount of how Science education started in the 20th Century, due to prominent scientists of the time justifying the relevance of science to modern life, and how it contributed to an insight into the natural world. It continued with a look at how, throughout the turbulent years from the 1920s to 1950s, there was growing concern amongst the public about the nature of science, and how scientific discoveries could be used against human society (for example, in the development of war technologies). However, this only strengthened the case for the teaching of Science in schools, so that society would become familiar with what scientists did, and how their work would be of benefit (DeBoer, 2000). This introduction of *science as a societal issue* helped to develop the notion of scientific literacy in the late 1950s.

With the approach of the 1960s, scientific knowledge was seen as strategic within society. Citizens who were knowledgeable about science would be more sympathetic towards the work of scientists, and their children would receive the kind of Science education that would allow success in this new society of increasing technological and scientific development (Laugksch, 2000). This became known as scientific literacy, the new purpose of Science education (DeBoer, 2000; Laugksch, 2000). Unfortunately, this new purpose of science education became lost in the late 1960s, as a number of Science educators came to know scientific literacy as the quest for greater scientific content and knowledge across the broad range of science fields (DeBoer, 2000), and there was a failure to deliver a clear and agreed definition of the term.

By the 1970s, many Science educators soon came to realise the repercussions of a persistent lack of consensus on the definition of scientific literacy (Laugksch, 2000; McEneaney, 2003) and how a focus on scientific content and knowledge could affect Science classrooms. They became concerned that the goal of scientific literacy for all had been overshadowed by excessive science content (DeBoer, 2000; Goodrum, Hackling, & Rennie, 2000). Advocates for scientific literacy then became promoters for the connection between technological advancements and scientific developments, attempting to use this relationship to ensure that scientific literacy for all students was again the broader goal of Science education, instead of a focus on scientific content and knowledge.

When the early 1980s came, the relationship between technology and science gained greater support, with the development of the *Science-Technology-Society* curriculum in the United States (DeBoer, 2000; Dillon, 2009). The aim of this curriculum was to promote how knowledge of the nature of scientific and technological developments interacted with society. In particular, there was to be a focus on any social issues that were science-related (for example, health and the environment), and that these were to be the drivers of curriculum topics. However, DeBoer (2000) explains that this proved to be highly controversial, as the focus on social issues and not in-depth scientific content and knowledge clashed with Science teachers' internal perspectives that scientific content should be the basis for all Science education. This need for a pedagogical shift in Science education prompted the need for Science education reform in the 1990s (DeBoer, 2000; Goodrum, et al., 2000).

Yore and Treagust (2006), in their paper *"The current realities and future possibilities of scientific literacy"*, adopt the OECD definition of scientific literacy as used in the 1999 Programme for International Student Assessment (PISA). It states that *"*[scientific literacy is] *the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and make decisions about the natural world and the changes made to it through human activity"* (p. 305).

Since 1999, the OECD has expanded their definition, and provided it in the 2009 PISA as:

> *an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the issues of science, as a reflective citizen (OECD, 2009, p. 14).*

In contrast, the *Australian Curriculum: Science* defines scientific literacy as:

> *the ability to use scientific knowledge, understanding, and inquiry skills to identify questions, acquire new knowledge, explain science phenomena, solve problems and draw evidence-based conclusions in making sense of the world, and to recognise how understandings of the nature, development, use and influence of science help us make responsible decisions and shape our interpretations of information (Australian Curriculum, 2011, p. 73).*

Giving students the ability to investigate the world and determine how it is being changed through human activity is listed as one of the benefits of teaching students scientific literacy in this new curriculum (Australian Curriculum, 2011).

With such variation in the meaning and use of the term, this investigation recognises that Science teachers may require clarification for what scientific literacy means for their classroom practice. Therefore, when the history of the term *scientific literacy,* as described by DeBoer (2000), led Norris and Phillips (2003) to summarise its usage into categories, an opportunity arose for this investigation to propose clarification of the term. The Norris and Phillips (2003) categories are:

> *"(a) knowledge of the substantive content of science and the ability to distinguish science from non-science; (b) understanding science and its applications; (c) knowledge of what counts as science; (d) independence in learning science; (e) ability to think scientifically; (f) ability to use scientific knowledge in problem solving; (g) knowledge needed for intelligent participation in science-based social issues; (h) understanding the nature of science, including its relationship with culture; (i) appreciation of and comfort with science, including its wonder and curiosity; (j) knowledge of the risks and benefits of science; and/or (k) ability to think critically about science and to deal with scientific expertise (p. 225)."*,

This research investigation now proposes that scientific literacy can be investigated in the curriculum using the following four key elements: 1. Scientific knowledge in its multiple representations; 2. Social relevance, 3. Cultural and contextual relevance; and 4. Critical reflective practice. The above categories of scientific literacy, along with the OECD and *Australian Curriculum: Science* definitions can be linked to these four key elements as follows:

1. Scientific knowledge in its multiple representations: *(a) knowledge of the substantive content of science and the ability to distinguish science from non-science; (c) knowledge of what counts as science; and (e) ability to think scientifically;*

2. Social relevance: *(b) understanding science and its applications; (g) knowledge needed for intelligent participation in science-based social issues; and (h) understanding the nature of science, including its relationship with culture;*

3. Cultural and contextual relevance: *(h) understanding the nature of science, including its relationship with culture; (j) knowledge of the risks and benefits of science; and (k) ability to think critically about science and to deal with scientific expertise;*

4. Critical reflective practice: *(d) independence in learning science; (f) ability to use scientific knowledge in problem solving; (i) appreciation of and comfort with science, including its wonder and curiosity; and (k) ability to think critically about science and to deal with scientific expertise*.

These key elements for investigating scientific literacy will be described in more detail in Section 2.3. They are also utilised in Chapter 3 as a basis for the Critical discourse analysis method, and throughout Chapter 4 to discover how scientific literacy is portrayed in the *Australian Curriculum: Science*.

1.3 Research Aim and Questions

Critical discourse analysis (CDA) will be used to explore how scientific literacy has been linguistically positioned in the *Australian Curriculum: Science*, to determine its importance to current Science educators in Australia.

Therefore, the aim of this investigation is:

> *To determine, using critical discourse analysis, what meaning and value has been placed on scientific literacy in the new Australian Curriculum: Science, and how Science teachers are expected to respond to this placement of scientific literacy in regards to their intentional teaching for it.*

Research questions that stem from this aim include:

1. What does the current literature say about scientific literacy and its importance for Science educators?

2. How does the new *Australian Curriculum: Science* represent scientific literacy as both concept and pedagogy?

3. How can Science educators combine the new *Australian Curriculum: Science* and intentional teaching for scientific literacy in a successful manner?

1.4 Scope of Research

This research investigation uses Critical Discourse Analysis to examine Version 3.0 of the *Australian Curriculum: Science* document, published in January 2012. Within the Critical Discourse Analysis methodology there will be three different levels of analysis. Firstly, a ‘macro’ look at the educational context surrounding the development of the *Australian Curriculum: Science* will be conducted. To assist with understanding how education policy and curriculum documents may have influenced the development of the *Australian Curriculum:* Science, the Hobart Declaration, the Adelaide Declaration, the *Statements of Learning for Science* and the Melbourne Declaration will also be examined. Secondly, a 'meso' level investigation will examine how the structure of the *Australian Curriculum: Science* document influences its interpretation by teachers. Finally, a 'micro' analysis of the language used throughout the documented will be completed, where the linguistic position of scientific literacy will be determined.

1.5 Research Design

The theoretical frameworks that informed this study are presented briefly here and elaborated further in Chapter Three.

Critical social theory, most commonly associated with Horkheimer, Adorno, Benjamin, Habermas and Marcuse (Leonardo, 2004; McLaughlin, 1999), aims to promote the role of criticism in education, and will be used as an overarching framework for this research. Science education requires students to experience classroom discourse that promotes criticism, deep analysis and the expansion of their conceptual understandings. Critical social theory encourages this shift from learning that is knowledge transmission towards learning that is knowledge transformation (Leonardo, 2004). In addition to this, the *New Learning* framework (Kalantzis & Cope, 2008) will be used to explore how the nature of education and learning, specifically with regards to Science education could influence Science curriculum development. This will show if the new curriculum is scientific content-driven, or focussed on preparing science learners for societies of the future. Furthermore, *Multiliteracies* and *Learning by Design* frameworks (Cope & Kalantzis, 2000) will be incorporated into the research design to compare scientific literacy to the different types of literacies that students of today require to interact in society.

From this it is expected that the nature of scientific literacy will be further explained, including its importance for all students.

The Critical Discourse Analysis method, based on the work of Fairclough (2003), is used to analyse the *Australian Curriculum: Science* to determine how scientific literacy has been linguistically positioned within the text. This will provide insight into how the language choices used in the document convey the importance placed on scientific literacy by the curriculum developers, and therefore the expected importance to be placed on it by Science teachers.

1.6 Expected Outcomes

It is expected that the findings of this research will provide awareness into whether the new *Australian Curriculum: Science* has been designed to promote scientific literacy and the application of this literacy to societal issues. Furthermore, this research will show if Science teachers can gain a clear understanding of scientific literacy and its importance in the teaching and learning of Science. However, the most important outcomes of this research are to provide Science teachers with a clear picture of the nature of scientific literacy, through development of the four elements of scientific literacy detailed in this investigation, and to provide Science teachers with recommendations on how to incorporate intentional teaching for scientific literacy into their teaching, whilst maintaining the integrity of the new *Australian Curriculum: Science*.

1.7 Significance of the Research

This research hopes to provide a significant contribution towards intentional teaching for scientific literacy in Australian classrooms. In their review of Australian

Curricula, Hackling, Goodrum and Rennie (2001) discovered that overall, Science curricula across all States and Territories provided future-driven curricula, with the goal of scientific literacy for all students. However, their research also discovered a gap between the ideal intentions of the curricula and the implementation in Science classrooms. Secondary Science students could see their Science curriculum as being irrelevant and content driven, with any practical investigations being pre-determined through 'recipe-style' experiments from textbooks (Hackling, et al., 2001). Teachers often confirmed that the curriculum was content-heavy, and that if the demands of the 'end-of-unit' test were to be met, there simply wouldn't be time to include targeted scientific literacy activities (Hackling, et al., 2001; Millar, 2006). With the introduction of the new *Australian Curriculum: Science*, an opportunity arises to delve into what it means to intentionally teach for scientific literacy, and whether such a heavy focus on scientific content is essential to producing scientifically literate students.

The *Australian Curriculum: Science* puts Science teachers on the verge of a new chapter in Science teaching, and it is important for this implementation to be underpinned by current research. With this new curriculum comes the opportunity to re-evaluate how Science is taught in Australian schools. If the importance of scientific literacy is overlooked, future Science students may be disadvantaged. Across the world, there seems to be consistent agreement that producing scientifically literate students is important. However, there have been suggestions that the general outcomes of Science education systems might to be failing at this task (Rennie, et al., 2007). This research endeavours to provide Science educators with recommendations about how they could prepare their students to be scientifically literate and contribute to the many scientific issues that will arise in the future.

1.8 Summary

Chapter One began with Section 1.1 outlining the background information of why intentional teaching for scientific literacy is important to Science education. In addition, due to the nature of scientific texts and the demands placed on the reader, Science students should be provided with opportunities to explore scientific text types, guided by their teachers. Science teachers may need to embrace strategies that clearly explain how science is portrayed in a variety of text types, so that students can develop aspects of scientific literacy. This will require a paradigm shift for many Science teachers, as they learn to 'let go' of content-driven curricula, and discover the value in teaching for scientific literacy.

Section 1.2 outlined the history of the term *scientific literacy*, and defined it in a number of ways, including the categories developed by Norris and Phillips (2003) both the 1999 and 2009 definitions provided by the OECD in the PISA documents, and the 2012 definition provided by the document at the focus of this investigation, the *Australian Curriculum: Science*. From this history, the categories developed by Norris and Phillips, and the OCED and *Australian Curriculum: Science* definitions, a set of key elements for clarifying and developing scientific literacy were proposed. These elements will now be further explained in Chapter Two, and Chapter Three will link them with the theoretical framework underpinning this research.

Section 1.3 outlined the main research aim of "determining, using critical discourse analysis, what meaning and value has been placed on scientific literacy in the new Australian Curriculum: Science, and how Science educators are expected to respond to this placement of scientific literacy in regards to their intentional teaching for it", including three research questions that stem from this aim. This was followed by section 1.4 outlining the scope of the research, and how the main focus document will be Version 3.0 of the *Australian Curriculum: Science*, released in 2012.

Sections 1.5 and 1.6 explained the research design and expected outcomes of this investigation, detailing how CDA will be used to discover the linguistic position of scientific literacy within the curriculum document. They detailed how this investigation can provide recommendations for Science teachers in Australia on how to incorporate intentional teaching for scientific literacy in their classrooms within this new curriculum structure.

Chapter One was concluded with Section 1.7, explaining how this research endeavours to provide Science educators with recommendations about how they could prepare their students to be scientifically literate and contribute to the many scientific issues that will arise in the future. This will help to ensure a focus on scientific literacy in Australian Science classrooms within the new *Australian Curriculum: Science*. Chapter Two will now examine scientific literacy in the Australian context, and investigate the alternative perspectives and definitions of the term, including a brief look into the future of scientific literacy.

Chapter 2: LITERATURE REVIEW

This section delves into scientific literacy, both in the Australian context and from a literature perspective. Section 2.1 begins with an introduction to science and scientific literacy in the Australian context, including a review of the current standing of scientific literacy achievement in Australia. This is followed by Section 2.2, which provides a detailed range of different perspectives on the current standing of scientific literacy in the literature. From these current perspectives, the key elements for developing scientific literacy proposed in Chapter One will be further examined in Section 2.3. These key elements are used to inform the CDA method outlined in Chapter 3. A summary of this chapter is provided in Section 2.4.

2.1 Science and scientific literacy in the Australian context

Science curriculum development in Australia over the past 15 years has shown a mixture of State, Territory and National approaches to curriculum reform. In 1993, a National Curriculum Statement for Science was produced, based on the mapping of each State's and Territory's curricula (Rennie, et al., 2007). The aim of this approach was to develop consistency across the nation in regards to science learning. However, soon after its release, this national curriculum initiative collapsed, and each State or Territory continued to follow its own curriculum agenda (Hackling, et al., 2001). A review of the current curriculum frameworks for each State or Territory now shows a combination of either complete adoption of the original national curriculum, little to no change from the original curriculum mapped in 1993, or a complete redevelopment of curricula to no longer resemble the mapped documents or the national initiative (Hackling, et al., 2001).

There have been calls for a common Australian Certificate of Education that includes a core of common curriculum elements, to ensure consistency across the

States and Territories (ACER, 2006). Rennie, et al. (2007), however, warn that the simple alignment of the different States' and Territories' curricula is unlikely to have a significant impact on the current problems within the teaching and learning of scientific literacy. They claim that because the current issues in Science education are due to the attitudes and perceptions of students, a whole different approach is required. Science educators need to be provided with a curriculum that promotes scientific literacy, has a broader context base and appeals to a wider range of students (Rennie, et al., 2007).

Between 1993 and 2003, the number of students leaving Australian secondary schools having studied any of the three main science subjects, Physics, Chemistry or Biology, has declined (Rennie, et al., 2007). In addition to this, results detailed in a report produced by the OECD Global Science Forum (2006) show that if students are presented with uninteresting scientific content or poor Science teaching at school, it leads to a negative experience that is detrimental to their future career choices. Therefore, it is important that the position of science in society, including the extensive range of career choices available and the increased influence science has on the future direction of society, be increased.

If a common national curriculum, or core of common curriculum elements, is to be developed, the OECD Global Science Forum recommends

> [the] *curricula should be redesigned to better reflect the reality of modern science and technology, and to emphasise their contributions to society. Specific actions can focus on…exposure to cutting-edge science… debates on the role and social relevance of science… and actions directed towards a 'humanisation' of science teaching. Teaching should also concentrate more on scientific concepts and methods rather than on retaining information only. These goals are particularly important in secondary education* (2006, p. 10).

With its development of the *Australian Curriculum: Science*, the Australian Curriculum, Assessment and Reporting Authority (ACARA) states this new curriculum will provide teachers with the core knowledge, understanding and skills of science to teach their students, and that the *Australian Curriculum: Science* will help develop each student's scientific view of the world (Australian Curriculum, 2011). To understand how this new curriculum may develop this scientific view and improve scientific literacy in Australian Science classrooms, the current standing of scientific literacy achievement in Australia must first be investigated.

2.1.1 The current standing of scientific literacy achievement in Australia

In 2009, the Organisation for Economic Cooperation and Development (OECD) conducted their Programme for International Student Assessment (PISA), assessing reading, mathematical and scientific literacy. The approach taken by the PISA in relation to scientific literacy was to assess a student's ability to apply their knowledge and skills in new situations, as opposed to assessing their mastery of science content (Thomson & DeBortoli, 2008). This included assessing students' abilities in the following three key competency areas:

1. ***Identifying scientific issues****: recognizing issues that are possible to investigate scientifically; identifying keywords to search for scientific information; recognising the key features of a scientific investigation,*

2. ***Explaining phenomena scientifically****: applying knowledge of science in a given situation; describing or interpreting phenomena scientifically and predicting changes; identifying appropriate descriptions, explanations, and predictions, and*

3. ***Using scientific evidence****: interpreting scientific evidence and making and communicating conclusions; identifying the assumptions, evidence, and*

reasoning behind conclusions; reflecting on the societal implications of science and technological developments" (OECD, 2009, p. 137).

An overview of the framework used by the OECD in the 2009 PISA can be seen in Figure 1 below.

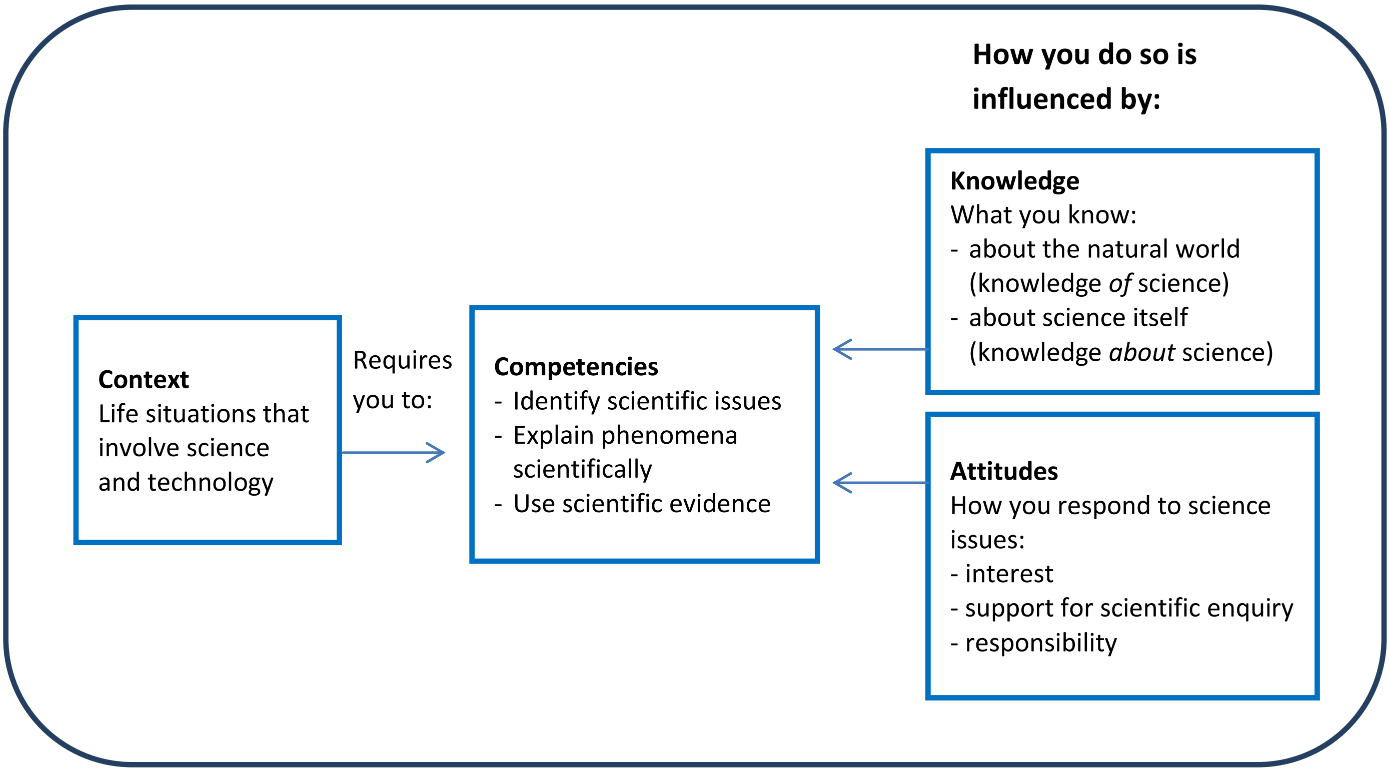


Figure 1: Framework for the PISA 2009 Science Assessment (OECD, 2009, p. 130)

In 2009, just over 14 000 students from 353 schools across Australia participated in the PISA, with their mean score for scientific literacy achieving 527. This is significantly higher than the OECD average of 501, ranking Australia 7th to only Shanghai – China, Finland, Hong Kong – China, Singapore, Japan and Korea (Thomson, De Bortoli, Nicholas, Hillman, & Buckley, 2011). The United Kingdom and the United States, along with the remaining 37 other countries, were significantly outperformed by Australian students in this internationally recognised assessment. When these results are compared to the 2006 PISA, Australia has shown no overall improvement, scoring an average of 529 for scientific literacy in 2006 (Thomson & DeBortoli, 2008).

These results, showing Australia consistently performing well above the OECD average, could lead educators and governmental bodies to assume that all is well with the teaching and learning of scientific literacy in Australia. However, in her report on the 2006 PISA, Hume (2009) reported that in Australia, current teaching practices which promote genuine scientific inquiry (which can lead to the development of scientific literacy) are insufficient. Moreover, from the 2006 PISA results, Thomson & De Bortoli (2008) warned of a danger, with Australian students underperforming in the "*explanation of scientific phenomena"* competency. Such a result could indicate that students lack mastery of scientific knowledge, facts, and their application. Their recommendation was that the Australian Government should ensure the primary focus of Science education is the development of scientific literacy (Thomson & DeBortoli, 2008). Since the results of the 2009 PISA seem to show no overall improvement in the scientific literacy of Australian students since 2006, it could be concluded that work should be done in the development of scientific literacy in Australia.

2.2 Perspectives on scientific literacy

As detailed in Chapter One, the first use of the term *scientific literacy* was by Paul deHard Hurd in 1958 (Holbrook & Rannikmae, 2009), with DeBoer (2000) providing an overview of the history of the term. This section aims to expand the use of the term, with section 2.2.1 proposing seven alternative definitions for scientific literacy; 2.2.2 will explain the difference between scientific literacy in its fundamental and derivative senses; and 2.2.3 will provide an insight into where conceptualisations of scientific literacy are expected to proceed in the future.

2.2.1 Alternative definitions of scientific literacy

One alternative definition of scientific literacy is based on Yore and Treagust's (2006) adoption the OECD definition of scientific literacy as used in the 1999 PISA, stating that *"*[scientific literacy is] *the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and make decisions about the natural world and the changes made to it through human activity"* (p. 305). Here, Holbrook and Rannikmae (2009) cite that even though the expanded OECD definition has been criticised by some, namely because of the way it is used as justification for an international written test, they still suggest that such a definition an appropriate for science education. Scientific literacy should not just be limited to an understanding of science, but be expanded to include an appreciation of science. DeBoer (2000) agrees, stating that scientific literacy will always be an expanded concept, because it is *"synonymous with the public's understanding of science" (p. 594).*

A second alternate view of scientific literacy stresses the need for students to be taught the nature of science and not just scientific content and knowledge. This is the *"education through science"* concept proposed by Holbrook (2010). This new way of teaching takes the emphasis off 'science through education' (which might be seen as the current focus of Science education), and puts it squarely on relating science to the needs of society. This new focus includes learning areas such as problem solving, creativity, perseverance, ingenuity, risk assessment and working as a team. The fundamental goal of *education through science* is that its students function as responsible citizens, and that they appreciate the significant role science plays in today's society (Holbrook, 2010). This investigation sees students functioning as responsible citizens in regards to how science and society interact as a key factor in the development of scientific literacy. This notion aligns with one of the scientific literacy categories provided by Norris and Phillips' (2003), where students need knowledge to intelligently participate in science-based social issues. Therefore, this idea plays a major role in the key elements for developing scientific literacy proposed by this investigation in Section 2.3.

Thirdly, a different perspective on scientific literacy is one provided by Yore, et al. (2003). Their focus is on the explicit inclusion of language in science, stating that *"language is an integral part of science and scientific literacy"* (Yore, et al., 2003, p. 691). With language being a means to doing and understanding science, as well as communicating that understanding to others, Yore, et al. (2003) state that all students of Science use written, visual and oral language, including various information sources to understand and then persuade others about science. The inquiry process of science stresses that knowledge claims, based on scientific arguments, must draw on text-driven evidence (Yore, et al., 2004). Freebody, Maton and Martin (2008) and Moje (2008) also support this suggestion of explicit literacy instruction in Science, or what is termed '*disciplinary literacy*'. A disciplinary literacy approach could ensure content-area teachers are focussed on the explicit teaching of literacy within their own area, and how the discourses of the content-area are developed, rather than trying to 'bolt-on' the literacy approaches of other content-areas.

These perspectives on scientific literacy that endorse the intentional teaching of literacy strategies in Science classrooms aim to ensure that all students are able to talk, read and write scientifically. These perspectives therefore underpin this investigation. Intentional teaching for scientific literacy could provide step-by-step instruction for students about how to understand how the text they encounter has been constructed, influenced by the author and presented to the reader. It also can allow students to evaluate how they are being persuaded as the reader by the science presented in the text, and teach them to analyse critically what influence the text has on the relationship between them, science and society. Therefore, it is worthwhile that the investigation of numerous forms of scientific text, especially persuasive text types, be included in the key elements for developing scientific literacy set out in this investigation in Section 2.3.

Although such a focus on the specific language aspects of scientific literacy as that provided by Yore, et al. (2003) is constructive, one should be careful to not lose sight of the many perspectives of scientific literacy. Both Holbrook and Rannikmae (2009), and Dillon (2009), propose a fourth alternative definition of scientific literacy, describing it as two currently held views on scientific literacy. One of these views is held by many Science teachers, where the central role of scientific literacy is the acquisition of knowledge. This view is built on the idea of scientific content, with the fundamental content and concepts of science being the most important. The second view of scientific literacy is broader, seeing it as the need to adapt to a rapidly changing world, ensuring each scientifically literate person has societal usefulness (Dillon, 2009; Holbrook & Rannikmae, 2009). This includes providing all students with an understanding of science and how it develops, whether a student is to become a scientist or not (DeBoer, 2000).

Although such different approaches to scientific literacy can cause barriers when attempts are made to shift the culture of Science education, both views agree that scientific literacy is more than just reading and writing, and must be used in a more metaphorical sense (Dillon, 2009; Holbrook & Rannikmae, 2009). This investigation stresses the importance of the second viewpoint (with the focus on scientifically literate students), and aims to determine if the new *Australian Curriculum: Science* has its focus on scientific content and the acquisition of knowledge, or if it also seeks to develop scientifically literate students with societal usefulness.

Yore and Treagust (2006) also agree that scientific literacy can be metaphorical, and produce students who could participate in the public debates about science issues. The emphasis of scientific literacy should be on both a literacy component that requires critical thinking, as well as an understanding of scientific content and knowledge. Murcia (2009) points out that historically, there has been a hierarchical understanding of how students develop scientific literacy. Students must initially start with understanding the science concepts, before they can then understand the nature of science, before finally linking their understandings to how science interacts with society.

Therefore, Murcia (2009) proposes a fifth alternative definition of scientific literacy, suggesting that students can blend these three levels of scientific literacy into a new understanding of the social context of science, with all its values and assumptions. If this new understanding of scientific literacy development is true, and teachers place an emphasis on the literacy component of scientific literacy, then this could enable students to develop both the knowledge and communication skills required to act as responsible citizens (Holbrook & Rannikmae, 2009). Underpinning their general Science Statements of Learning, the Ministerial Council for Education, Employment, Training and Youth Affairs (MCEETYA) in Australia also defines scientific literacy with regards to students becoming informed citizens who can contribute to debates and make reasoned judgements and social issues in science (Rennie, et al., 2007).

Alternatively, in an effort to avoid the controversial *scientific literacy* term described above, DeBoer (2000) instead proposes a sixth different viewpoint, one that defines Science education in terms of the goals it should aim for. These include:

> *1. Teaching and learning about science as a cultural force in the modern world; 2. Preparation for the world of work; 3. Teaching and learning about science that has direct application to everyday living; 4. Teaching students to be informed citizens; 5. Learning about science as a particular way of examining the natural world; 6. Understanding reports and discussions of science that appear in the popular media; 7. Learning about science for its aesthetic appeal; 8. Preparing citizens who are sympathetic to science; and 9. Understanding the nature of importance of technology and relationship between technology and science (DeBoer, 2000, pp. 591-593).*

This strategy, of not using scientific literacy as one of the goals for Science education (because it is yet to be fully comprehended amongst Science educators), but encompassing scientific literacy into nine goals, could prove to be a direction in Science curriculum reform. Some current Science educators, who have the belief that scientific content should be the basis of all Science curricula, may find the shift to 'nine goals of education' easier than a shift to 'scientific literacy'. Of these goals, this investigation sees "*teaching students to be informed citizens",* and "*understanding reports and discussions of science that appear in the popular media" (DeBoer, 2000, pp. 591-593)* as significant to the development of scientific literacy. If these two goals can be at the fore-front of intentional teaching for scientific literacy, then learners can develop scientifically and socially responsible practices.

A seventh perspective of scientific literacy is one presented by Holbrook (2010). He notes how advancements in technologies are behind most of the new developments in society, and that Science education should therefore reflect the relationship between science and technology. So, Holbrook (2010) proposes a new term, *scientific and technological literacy* (STL), to ensure Science education recognises the role it plays in new social technological developments. This new term would focus on social issues and developments, and not place a high value on the regurgitation of scientific content and knowledge, to ensure the essence of scientific literacy is maintained.

Throughout all the years of uncertainty and confusion surrounding the definitions and different perspectives of scientific literacy, the term itself has remained. Although the different philosophies of how scientific literacy could be taught can hinder curriculum change, it is still used by a diverse range of interest groups as a justification for influencing and changing the way science is being taught in schools today (Dillon, 2009). Clearly the term 'scientific literacy' is deceptive, appearing on the surface as a simple term, yet the underlying concepts are numerous, with a number of different interpretations, perspectives and assumptions. Laugksch (2000) even puts it in the same class as words like justice and liberty, that contain seemingly simple qualities, but under close scrutiny become more complex and controversial.

The central issue that still remains though is the desire for a definition of scientific literacy that could be used to reform Science education and influence the system as a whole (Yore & Treagust, 2006). Teacher professional development programs should embrace the view that effective and intentional teaching for scientific literacy in all classrooms requires Science educators to understand the term itself. Teachers require direction from both the research and philosophical backgrounds behind scientific literacy, and to be supported by the curriculum. Only when clear applications for scientific literacy are provided, and assistance is given to teachers in developing pedagogies that promote scientific literacy, will students then be able to learn to communicate scientifically and successfully participate in the world around them (Rennie, et al., 2007). This investigation aims to fulfil in part this requirement for teachers to have direction when trying to embrace scientific literacy, and provide applications of scientific literacy and how it can be used in the classroom. This is shown with the development of the key elements for investigating scientific literacy presented in Section 2.3.

2.2.2 Scientific literacy in the fundamental and derived senses

In this subsection of the chapter, the ideas presented by Norris and Phillips (2003) about the difference between the fundamental and derived senses of scientific literacy will be explored.

> *"Reading and writing when the content is science [is] the fundamental sense of scientific literacy, and being knowledgeable, learned, and educated in science [is] the derived sense of scientific literacy."*
>
> (Norris & Phillips, 2003, p. 224)

Scientific literacy in the fundamental sense focuses on the tools of reading and writing. These tools are not just used in Science education, nor are they seen as necessary for just storing scientific content and regurgitating it on assessment items. Language, including using the tools of reading and writing, are seen as fundamental requirements of constructing science (Yore, et al., 2004). Reading and writing are constitutive parts of Science education. If they are removed, the very essence of Science education can be lost (Norris & Phillips, 2003). However, educators should be careful to not fall into the trap of identifying scientific literacy as only reading and writing scientifically. Scientific literacy is more than that, as has been identified in the literature above. This investigation places a high value on scientific literacy incorporating multiliteracies, as can be seen by the theoretical frameworks underpinning this research, and that scientific literacy should include the multiple representations of knowledge.

To understand how multiple representations of knowledge are significant to Science education, one must investigate the challenges in understanding the technical text found in science discourses and contexts. Studies in the comprehension of technical text (based on discourse cognitive theory) show that a lack of comprehension is most likely to be the result of one of two factors: either the readers were not able to adjust their current knowledge to accurately comprehend the new knowledge presented in the text in different ways; or no specific reading strategy was used to assist in comprehension (Dijk, 2011)

In addition to a lack of comprehension, how readers position themselves in relation to the text they are reading also influences their ability to understand technical texts (Norris & Phillips, 2003). One possibility is for a dominant stance towards the text to be adopted. In this position, the reader allows their background ideas and beliefs to overpower the text information. This situation ensures the meaning of the text is taken in relation to what the reader previously understands and believes. The text can then be criticised and evaluated against these beliefs (Norris & Phillips, 2003).

In contrast, a deferential stance towards the text could be adopted by the reader, whereby the reader allows the text to overshadow their background knowledge and beliefs. This then causes the reader to accept whatever the text is saying, even if it contradicts their beliefs (Norris & Phillips, 2003). It could be speculated that the nature of science texts traditionally presented to students in school classrooms assumes that students take this deferential stance towards the text, and that the teacher, curriculum developer and textbook writer are 'right' and not to be challenged by students. There is a balance of agency that ensures the teacher and text are dominant, with the students being subservient (Kalantzis & Cope, 2008). This deferential stance that students can automatically take towards both their

Science teacher and the text they are presented with is what this investigation seeks to disrupt. Students can be taught how to analyse critically any scientific information presented, in various multimodal form, and if this happens, it is likely that students might be better prepared to reflect on their learning and make informed and socially appropriate decisions about how the scientific information they are presented with might influence their lives and the lives of others.

As well as overcoming the deferential stance taken by students, if the focus of Science education is not scientific literacy for all, then students may not be encouraged to challenge the science texts presented. This may be the case even when the text contradicts their personal beliefs and prior knowledge. Students can be taught how to differentiate between statements in the text that assume, infer, hypothesise, conclude, justify an action, express a doubt or provide evidence for a claim (Norris & Phillips, 2003). If the students fail to understand the difference between these types of scientific statements, then not only could they have taken a deferential stance towards the text and let it overwhelm them, they may not have fully comprehended the technical text they are reading, and missed the scientific content altogether (Dijk, 2011; Norris & Phillips, 2003).

Norris and Phillips (2003) describe how if the fundamental sense of scientific literacy is to be exposed to students, they should be taught how to cope with different science texts and how to understand what they might mean. Intentional teaching for scientific literacy can therefore include strategies for comprehension, evaluation and reflection. Traditional reading comprehension strategies developed when students are young are not normally aimed at developing deep understandings of scientific or technical texts. Therefore, new comprehension strategies can be learnt. Based on discourse cognition theory, one such strategy showing promise is the use of *self-explanations* of the text, where the student generates his/her own understanding of each sentence whilst reading (Dijk, 2011). This method allows the reader to comprehend the text, sentence by sentence, to determine how the new material presented relates to the reader's current understanding, beliefs and ideas. Due to the expansive nature of the science texts to which students can be exposed, this new comprehension strategy could assist students in determining when they come across the same text expressing different ideas, or the same ideas being expressed in different texts (Norris & Phillips, 2003). This comprehension strategy demonstrates one way intentional teaching for scientific literacy could be incorporated into the Science classroom.

Due to the evidence-based nature of science, teaching literacy in the fundamental sense can also mean teaching students to question the underlying evidence that may or may not be provided by the text. There needs to be a shift in the balance of agency between the teacher, text and student, so that learners will end up as makers , not just receivers, of knowledge (Kalantzis & Cope, 2008). Science students can learn to question critically and reflect on the information the text is providing, neither taking a dominant nor differential stance, but a critical one (Norris & Phillips, 2003).

Another component of scientific literacy in the fundamental sense is the use of genres. In this area, genres that include *"description, directions, explanation, and argumentation are central components of the fundamental sense of scientific literacy"* (Yore, et al., 2004, p. 349). Because of this, Science educators might want to start diversifying the writing tasks given to Science students, helping to motivate and challenge them. No longer can the generic expository genres fully satisfy the development of scientific literacy (Yore, et al., 2004). This use of different genres and diversifying writing tasks in Science education links clearly with one of DeBoer's goals of scientific literacy, "u*nderstanding reports and discussions of science that* *appear in the popular media"* (DeBoer, 2000, pp. 591-593). For students to become scientifically literate, this investigation deems the use of different genres as crucial, because science is not normally presented in the current media (and to society in general) in the standard expository genre styles seen in science classrooms.

If Science educators are able to develop students' fundamental sense of scientific literacy, then the derived sense of it may follow. Holbrook & Rannikmae (2007) summarise this by stating that the essence of multi-dimensional scientific literacy develops in students the ability to *"(a)…act in a responsible manner within the community…; (b)… function within the world of work….; and (c) [posses] the conceptual background or skills of learning to learn to cope with a need-to-have relevant public understanding of science and technology in a changing society" (p. 1353).* Even though students who may not develop scientific literacy can still play an important role in addressing the wide variety of issues in society, they may struggle with issues that are inherently science-based. Therefore, if both the senses of scientific literacy described by Norris and Phillips (2003) are developed, students may acquire the scientific understanding and social skills required to interact with intrinsically science-based issues.

2.2.3 The future of scientific literacy and science curriculum reform

The previous subsections have outlined the history and development of scientific literacy in the current literature. This subsection will summarise proposed future directions of scientific literacy from the literature, and the implications for Science curricula.

With their research into the multi-dimensional nature of scientific literacy, Norris and Phillips (2003) suggest the future for scientific literacy as one where Science educators address the imbalance between the fundamental and derived senses of scientific literacy. Science teachers should not continue with the view that science is the study of disconnected knowledge, facts, laws and theories. Moreover, Science courses could improve by addressing the fundamental sense of scientific literacy (where reading, writing and comprehension of texts and contexts are paramount), to help students be exposed to the interconnectedness of science as well as its construction (Norris & Phillips, 2003). In fact, to have effective strategies that incorporate literacy into the curriculum, Luke and Freebody (2008) insist teachers draw on a range of procedures, from cracking the linguistic codes of text to giving students the ability to analyse it critically, ensures the intentional teaching of literacy is successful.

Fang and Wei's (2010) future for scientific literacy is one that follows this line of thought, and incorporates critical reading time into Science classrooms. They suggest that the benefits of targeted reading programs in Science will not only include an increase in students' reading proficiency, but also an increase in effective scientific content learning as well. Alvermann, et al. (2011) also state that this approach should be considered in Science education reform, as the development of reading comprehension (including situating the text within the broader social context) and the learning of scientific content can happen simultaneously. This targeted reading approach can assist in the development of scientific literacy for all Science students, and may still be embraced by Science educators, as the focus on scientific content is not completely lost. However, Fang and Wei (2010) also acknowledge that there is relatively little research into how one could incorporate reading into a secondary school Science program, and what impact it would have on student learning.

DeBoer (2000) describes the future of scientific literacy as one where Science curriculum developers and educators should prioritise the connections between the many different goals of Science education, so that Science curricula can meet as many of them as possible. This can include students being introduced to the issues in society that science provokes, with the hope that they understand enough and care enough about science that they take an interest in it as adults. If the future implications for scientific literacy as described by DeBoer (2000) are to be realised, then teachers need to be free to organise their Science teaching in a way that encompasses as many goals as possible. This includes selecting scientific content that they are comfortable teaching, and that makes the most sense to the course and to the students they are teaching. This investigation aims to discover if such freedom has been incorporated in the *Australian Curriculum: Science.*

In addition to this, the future for scientific literacy supported by many in the literature, is that the teaching of Science should concentrate on how it relates to social contexts and issues (Holbrook, 2010; Kolstø, 2001; Millar, 2006; Pouliot, et al., 2010; Rennie, et al., 2007; Tomas, Ritchie, & Tones, 2011; Yore, et al., 2004). Students should be provided with a Science curriculum that allows them to question how science is being created and portrayed in society. Further, students should be encouraged to not be overwhelmed by the scientific content presented. This could lead to the belief that they cannot engage with science issues of today, due to a lack of science knowledge (Kolstø, 2001).

Instead, if education through learning about socio-scientific issues takes place, the focus may shift to the moral and ethical viewpoints of the students (Tomas, et al., 2011). There can be more emphasis placed on the discourses used to present the socio-scientific issues, and the curriculum could encourage students to argue and debate ethics and funding, analyse data and evidence, and use critical thinking and problem solving techniques (Millar, 2006; Pouliot, et al., 2010; Tomas, et al., 2011; Yore, et al., 2004). Through this type of inquiry-based learning about socio-scientific issues, the goal of Science education can shift to one where students engage meaningfully with both the scientific content and nature of science, and become life-long learners of both.

However, Millar (2006) does warn that with a society-focused Science curriculum inevitably comes a trade-off in time spent completing practical activities. Therefore it is important that Science curriculum developers achieve a balance between the study of socio-scientific issues for improved scientific literacy, and maintaining the nature of science through investigation and exploration. Furthermore, to ensure these new ideas for the future of scientific literacy are successful, Hackling, et al. (2001) insist there must be teacher professional development programs. Resources can be used to show teachers how to incorporate the abovementioned ideas into practical teaching strategies, including demonstrations of scientific literacy in action, and the beneficial outcomes for students. This investigation aims to provide key foci for teachers when they attempt to incorporate scientific literacy into their Science classrooms. It aims to make visible any indications that the new *Australian Curriculum: Science* document provides in relation to how the development of scientifically literate students can be achieved.

2.3 Key elements for developing scientific literacy proposed by this investigation

Based on the historical developments and definitions of scientific literacy provided in Chapter One, and the different perspectives detailed in Sections 2.1 and 2.2 above, the following list of key elements for developing scientific literacy have been proposed. These elements will be used in conjunction with CDA (as outlined in

Chapter Three) to determine how scientific literacy has been linguistically positioned within the *Australian Curriculum: Science*.

Element 1: Scientific knowledge in its multiple representations

> Students should know enough scientific content and knowledge to distinguish science from non-science, so that they can critically analyse ‘science’ as it is presented in the media (DeBoer, 2000; Norris & Phillips, 2003).

Element 2: Social relevance

> Students need scientific knowledge to intelligently participate in science-based social issues, adapt to a rapidly changing world, function as responsible and informed citizens, and have societal usefulness (DeBoer, 2000; Dillon, 2009; Holbrook, 2010; Holbrook & Rannikmae, 2009; Norris & Phillips, 2003).

Element 3: Cultural and contextual relevance

> Students should understand the relevance of science to oneself, to culture and to their community (DeBoer, 2000; Holbrook & Rannikmae, 2007).

Element 4: Critical reflective practice

> Students can develop reflective practices, examining how the science knowledge presented influences their own beliefs and pre-conceived

ideas, and if the information presented has strong-enough evidence to challenge those ideas (Norris & Phillips, 2003), in an effort to develop as reflective citizens.

These elements will be revisited at the end of this research investigation to develop recommendations, from both the literature and the nature of scientific literacy as detailed in the *Australian Curriculum: Science* document, so that Science educators can have direction and practical applications when incorporating scientific literacy in their Science classrooms.

2.4 Summary

This chapter began with an introduction to science and scientific literacy in the Australian context. Section 2.1 explained the calls that have been made for a common Australian Certificate of Education, however Rennie, et al. (2007) warned that the simple alignment of different curricula is unlikely to have a significant impact, because Science teachers need to be provided with a curriculum that promotes scientific literacy. This was followed by Section 2.1.1 detailed the achievement of Australian students on the 2009 PISA.

Section 2.2 examined what current literature says about scientific literacy, including its alternate definitions, dimensions and perspectives presented in Subsection 2.2.2. This included viewpoints from: Yore and Treagust; Holbrook & Rannikmae; Freebody, Maton and Martin; Moje; and Dillon. Alternative proposals that tried to redefine scientific literacy were also examined. This included Murcia's (2009) proposal of a new understanding of how students develop scientific literacy, DeBoer's (2000) view that Science education should be defined in terms of the goals it should aim for, and Holbrook's (2010) *scientific and technological literacy* (STL) term to ensure Science education recognises the role it plays in new social technological developments.

Subsection 2.2.1 concluded with recognition that the central issue still remaining is the need for a definition of scientific literacy that can be used to reform Science education and influence the system as a whole (Yore & Treagust, 2006). If teachers can be provided with clear applications for scientific literacy, students may then be able to learn to communicate scientifically and successfully participate in the world around them (Rennie, et al., 2007).

Subsection 2.2.2 examined scientific literacy in the fundamental and derived senses, as presented by Norris and Phillips (2003). Their position was that scientific literacy in the fundamental sense focuses on the tools of reading and writing, and this was supported by Van Dijk's (2011) view that a lack of comprehension is most likely to be the result of one of two factors, either the readers were not able to adjust their current knowledge to accurately comprehend the new knowledge presented in the text, or no specific reading strategy was used to assist in comprehension.

In addition to this, there was also discussion of Norris & Phillips' (2003) assessment that due to the nature of science texts traditionally presented in school classrooms, students can take a deferential stance towards the text. Kalantzis & Cope (2008) called for a shift in the balance of agency between the teacher, text and student, so that learners can end up as makers of knowledge, not just receivers of it. Subsection 2.2.2 concluded with a look at the use of genres as a component of scientific literacy, and how Yore, et al. (2004) suggest Science educators diversify the writing tasks given to Science students.

The examination of current views on scientific literacy, its alternative definitions, dimensions and perspectives, was concluded in Subsection 2.2.3, with a brief glance at the future of scientific literacy and curriculum reform. Norris & Phillips (2003) suggest the future for scientific literacy as one where Science educators address the imbalance between the fundamental and derived senses of scientific literacy, reinforced by Luke and Freebody's (2008) proposal that a range of strategies should be used to ensure the effective teaching and learning of disciplinary literacies.

An investigation was also conducted into Fang and Wei's (2010) future for scientific literacy, as it is one that promotes the incorporation of reading time into Science classrooms. This future was also shared by Alvermann, et al. (2011), who suggested that the development of reading comprehension and the learning of scientific content can happen simultaneously.

Subsection 2.2.3 continued with a look at DeBoer's (2000) description of the future of scientific literacy, one where Science curriculum includes students being introduced to the issues in society that science provokes. This future for scientific literacy was supported by many in the literature, and concentrates on the discourses used to present socio-scientific issues (Holbrook, 2010; Kolstø, 2001; Millar, 2006; Pouliot, et al., 2010; Rennie, et al., 2007; Tomas, et al., 2011; Yore, et al., 2004).

Section 2.2 finished with a caution from Millar (2006), stating that with a society-focused Science curriculum, there may come a trade-off in time spent completing practical activities, and an insistence from Hackling, et al. (2001) that there should be teacher professional development programs to support the incorporation of the ideas surrounding the future of scientific literacy into practical teaching strategies.

Chapter Two was concluded with Section 2.3, where the four Key Elements for developing scientific literacy proposed by this study were described. These included: Scientific knowledge in its multiple representations; Social relevance; Cultural and contextual relevance; and Critical reflective practice. Chapter Three will now outline the theoretical and conceptual frameworks that underpin this study, and explain the Critical Discourse Analysis methodology.

Chapter 3: THEORETICAL FRAMEWORK and METHODOLOGY

In this Chapter, the theoretical and conceptual frameworks underpinning this research investigation will be explored, and the use of Critical Discourse Analysis (CDA) as the methodology explained. Section 3.1 will begin to unpack the conceptual framework designed specifically for this study, including Section 3.1.1, where critical social theory (the underlying theoretical framework of this study), will be briefly explained. This will be followed by Section 3.1.2, where a summary of the main points of the *New Learning* Framework, as presented by Kalantzis and Cope (2008), will be provided. This will also include an explanation of the relationship between this framework and the conceptual framework of this study.

Exploring the relationships between the conceptual and theoretical frameworks of this study will continue in Section 3.1.3, where the *Multiliteracies*, and subsequently *Learning by Design*, frameworks, as presented by the New Learning Group (Cazden, Cope, Fairclough, & Gee, 1996; Yelland, Cope, & Kalantzis, 2008), will be summarised. Section 3.2 will bring these theoretical and conceptual frameworks together in an explanation of the theory behind using CDA to discover the linguistic position of scientific literacy in the *Australian Curriculum: Science*. The specific method of CDA used in this investigation will be outlined in Section 3.2.1. This Chapter finishes with a summary in Section 3.3.

3.1 Conceptual Framework for this study

As can be recalled from Chapter 1, the aim of this investigation is:

> *To determine, using CDA, what meaning and value has been placed on scientific literacy in the new Australian Curriculum: Science, and how Science teachers are expected to respond to this placement of scientific literacy in regards to their intentional teaching for it.*

This section details how the theoretical frameworks of *New Learning* and *Multiliteracies*, as well as the perspectives on scientific literacy detailed in the literature investigated in Chapter Two, influence the lens through which the methods of this research study are viewed. It also explains how the above research question will be answered. This section explains each of the theoretical frameworks that underpin this study, and outlines why the combination of these frameworks is significant to the analysis of the *Australian Curriculum: Science* document being undertaken.

To begin, the conceptual framework for this study is seen in Figure 2 below:

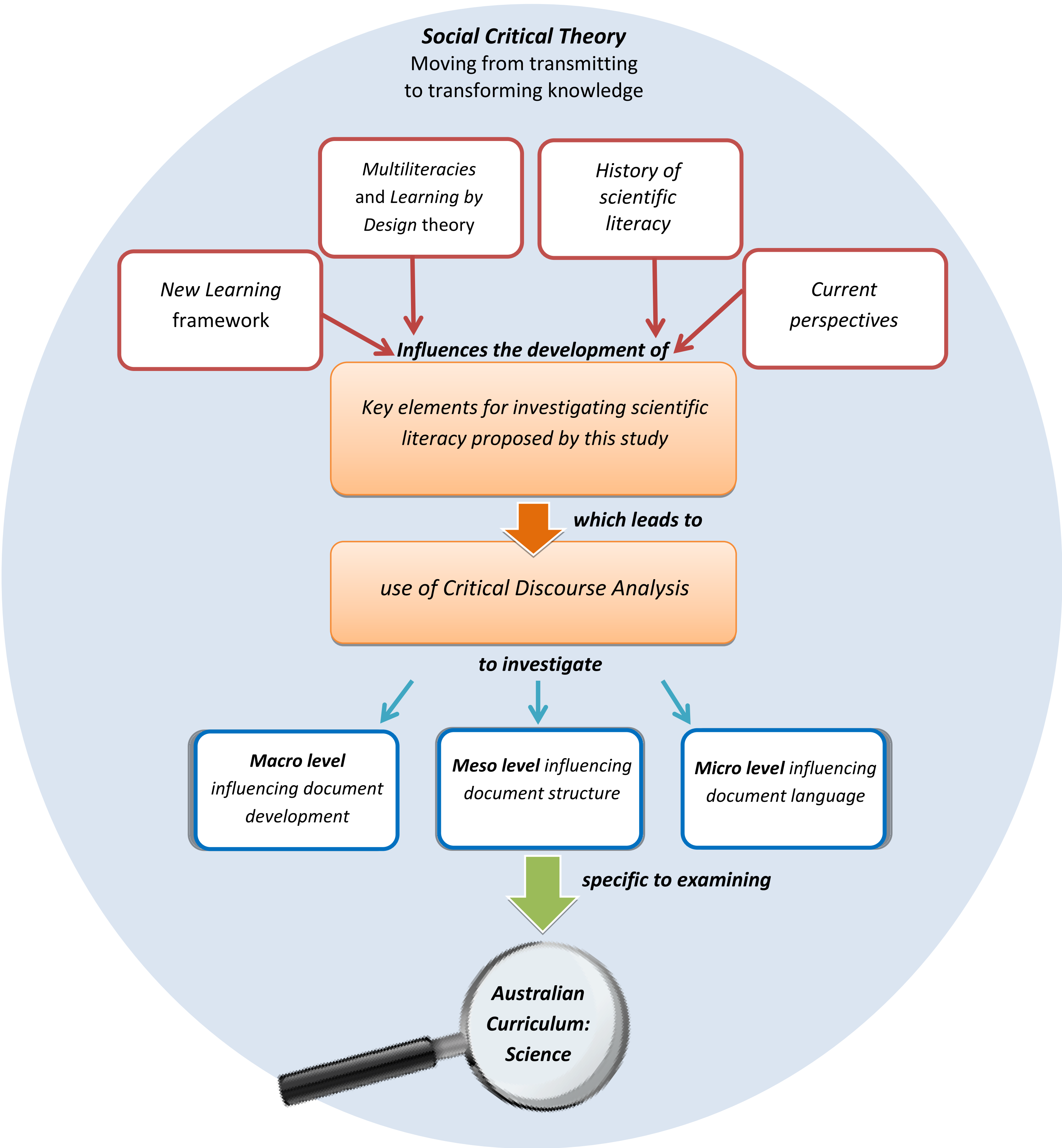


Figure 2: Graphical representation of the conceptual framework of this study

3.1.1 Critical Social Theory

As can be seen in Figure 2 above, critical social theory is the theoretical standpoint that underpins this research investigation. If critical social theory, as proposed by Horkheimer, Adorno, Benjamin, Habermas and Marcuse (Leonardo, 2004; McLaughlin, 1999), is the basis of pedagogy, then one could expect quality learning outcomes for all students, based on the notion that students should be taught to reflect critically on their learning and the society in which they live (Carrington & Selva, 2010; McLaughlin, 1999). Learning should not just be the transmission of knowledge; it should be the transformation of knowledge.

Critical social theory proposes that *"quality education is as much about teaching students the ability to read the world more critically (ideology critique) as it is imagining a better world that is less oppressive (utopian critique)"* (Leonardo, 2004, p. 16). The idea that learning is content-driven, with educators as the conduit through which knowledge simply passes without thought into the minds of the learner, does not reflect the current research into Science education, nor what learners in today's society may need. Curriculum should not be a body of knowledge that needs to be 'deposited' into the minds of students; it should be meaningful, and incorporate political and social dynamics that influence their daily lives (Bayne, 2009).

Critical social theory has also influenced the development of more recent educational philosophies, including critical pedagogy. Critical pedagogy is described as *"a way of thinking about, negotiating, and transforming the relationship among classroom teaching, the production of knowledge, the institutional structures of the school, and the social and material relations of the wider community, society, and nation-state"* (McLaren, 1998, p. 441). It suggests that students bring their own passions and desires to the learning process, and that they can be motivated by these (Giroux, 2004). Both critical social theory and critical pedagogy attempt to connect student learning with everyday life, reinforcing the belief that learning is critically dependent on the relationships between the students, educational professionals and society as a whole (Giroux, 2004).

This research investigation suggests that for scientific literacy to develop, Science learning could move beyond both the transmission and even transformation of knowledge, into a world where students are able to *actively participate* in the socio-scientific issues of today and tomorrow. Not only can students then attempt to transform the science knowledge they encounter, through critical analysis of how the knowledge has been constructed and the conclusions scientists and society draw, students may then become *active and responsible citizens*, intelligently participating in socio-scientific issues, and reflecting on the influences that science and society have on each other.

For educators to understand how scientific literacy is greater than just the transmission or transformation of knowledge, the elements for investigating scientific literacy need to be clearly defined. The four key elements for developing scientific literacy proposed by this investigation are influenced by both critical social theory and critical pedagogy:

> *Element 1: Scientific knowledge in its multiple representations*: Students should know enough scientific content and knowledge to distinguish science from non-science, so that they can critically analyse 'science' as it is presented in the media (DeBoer, 2000; Norris & Phillips, 2003).
>
> *Element 2: Social relevance*: Students need scientific knowledge to intelligently participate in science-based social issues, adapt to a rapidly changing world, function as responsible and informed citizens, and have

societal usefulness (DeBoer, 2000; Dillon, 2009; Holbrook, 2010; Holbrook & Rannikmae, 2009; Norris & Phillips, 2003).

Element 3: Cultural and contextual relevance: Students should understand the relevance of science to oneself, to culture and to their community (DeBoer, 2000; Holbrook & Rannikmae, 2007).

Element 4: Critical reflective practice: Students can develop reflective practices, examining how the science knowledge presented influences their own beliefs and pre-conceived ideas, and if the information presented has strong-enough evidence to challenge those ideas (Norris & Phillips, 2003), in an effort to develop as reflective citizens.

This research investigation aims to determine if the *Australian Curriculum: Science* promotes scientific literacy, by examining the language choices made by the curriculum developers. To assist in this endeavour, the key elements outlined above will be used as a focal point. If the *Australian Curriculum: Science* has a focus on the scientific content to be delivered, and not the development of scientific literacy, where students are critically analysing the position of science within society, then teachers may not be able to embrace critical pedagogy and connect student learning with the society in which they live.

3.1.2 New Learning

The *New Learning* framework, as presented by Kalantzis and Cope (2008), is a theory of learning that provides ideas for what the future of education could look like. As seen in Figure 2 above, this framework influences the development of the key elements of scientific literacy proposed by this study. *New Learning* asks all involved in the education process to examine how the strategies that are used to meet the needs of the current learners are developed, and whether those strategies are taking the new social conditions of those learners into account. The key element for developing scientific literacy influenced by this framework is:

> *Element 3: Cultural and contextual relevance:* Students should understand the relevance of science to oneself, to culture and to their community (DeBoer, 2000; Holbrook & Rannikmae, 2007).

This is due to the *New Learning* framework suggesting the formation of a new breed of professional educators, with new skills and sensibilities, so that their learners have the greatest chance of succeeding in a society that is changing dramatically (Kalantzis & Cope, 2008).

New Learning is based on four foundational values and principles. Firstly, diversity is a key component of *New Learning*, as it reflects contemporary society and should mould thinking about education. The notion that 'one-size-fits-all' schooling may no longer be valid, as it may not meet the needs of today's learners in this ever-changing society. Diversity must be understood in its broadest definition, so that differences in motivation, life experiences and knowledge, as well as the ever-changing destinations of learners are acknowledged. Therefore, education under the *New Learning* framework can satisfy the need for "*highly creative problem solvers able to re-imagine and reinvent entire ways of living in order to address increasingly urgent social and environmental challenges"* (Kalantzis & Cope, 2008, p. xvii).

The second foundation principle of *New Learning* is the cultivation of deep knowledge through education. No longer may it be acceptable to provide learners with 'surface knowledge' of various abstract concepts and processes. Education within a *New Learning* framework should be grounded in epistemology, the study of knowledge and justified belief. Students could strive to understand the nature of knowledge creation and the extent to which humans know.

Thirdly, *New Learning* is based on the principle that learning should be designed and tracked over time. Educators have a responsibility to provide learning experiences that are purposefully designed, to provide the greatest outcomes for students. Moreover, learner achievement should be tracked over time, to ensure what educators believe to be effective learning experiences are actually achieving what they set out to do. According to this framework, the success of educators is measured by learner performance (Kalantzis & Cope, 2008).

Finally, the fourth grounding principle of *New Learning* is that education is a global commodity, and that education with a *New Learning* framework is applicable anywhere in the world. With changing technologies, economies and cultures comes the need for knowledge competencies and sensibilities that can be provided by an education grounded in *New Learning*. Teachers and learners are facing the same problems around the globe, and therefore a framework that is applicable to all societies is required. However, education should not focus entirely on the global problem, and as the first principle of *New Learning* outlines, diversity at the learner level must be acknowledged. Moreover, if the diversity of learners at the local level can be navigated, then this should also be able to occur globally (Kalantzis & Cope, 2008).

In addition to these grounding principles, this framework is also grounded in an analysis of the recent past and present states of education, which can provide insights into what education could look like under a *New Learning* framework. These are detailed in Table 1 below.

Table 1: Summary of different approaches to pedagogy and curriculum across the modern past, the more recent times, and New Learning (Kalantzis & Cope, 2008, p. 208)

Pedagogy, curriculum and education	**Mimesis: The modern past**	**Synthesis: More recent times**	**Reflexivity: New learning**
Dimension 1: Pedagogy	Acquiring received knowledge (facts, theories, literatures) and being able to repeat what one has acquired in a test.	'Understanding' as learners deconstruct and reconstruct knowledge and come up with 'right' answers on 'their own'.	Shunting backwards and forwards between different things you can do to know, connecting with diverse learning experiences, creating deeper and broader knowledge, and reconnecting with the world in purposeful ways.
Dimension 2: Curriculum	Prescribed courses of study. A clear inside/outside distinction – outside knowledge copied inside the school.	School-based curriculum with a broader range of choice according to relevance, needs and diversity. Learner constructivism, the self-assembling individual knower; bringing in the outside of the school in a limited way through the recognition of differences, but often without addressing structures of inequality.	Alternative learning pathways to achieve comparable learning outcomes. Curriculum that supports a society in which agency has been rebalanced. Auto-production of knowledge; ubiquitous education.

What can be seen from the *New Learning* Framework is a focus on the learner and the environments where they learn, and the changing nature of society in which they are living, not the educational institution where learning is 'supposed' to happen. This study is influenced by the values and possibilities in *New Learning*, particularly in regards to Dimension 2: Curriculum, as there is the potential for students to see education as critical to their everyday lives, and the suggestion that educators evaluate their pedagogy and beliefs about current education policies and procedures.

Therefore, these principles of *New Learning* influence this study to explore the nature of the curriculum developed in the *Australian Curriculum: Science*. As was seen in Table 2, the *New Learning* framework details how curriculum development has moved from prescribed courses of study in the modern past, to school-based curriculum with a broader range of choices in the more recent past. However, curriculum could now move to ubiquitous education, supporting alternative learning pathways and a rebalancing of the power relationships between teachers and students.

Although the study recognises that many decisions made about curriculum delivery (including subject choices and alternative learning pathways) are determined at the school level, and not by the curriculum documents themselves, it is suggested that this *New Learning* framework is valid when investigating the *Australian Curriculum: Science*. This is because the *New Learning* framework can provide future ideas for curriculum development, and provide teachers with the proposal that curriculum should be designed to facilitate learning in the changing society in which students reside.

3.1.3 Multiliteracies and Learning by Design

The key elements of scientific literacy proposed by this study are also influenced by the *Multiliteracies* and *Learning by Design* frameworks. Cope and Kalantzis, along with the New London Group, propose that traditional ideas of literacy pedagogy need to be extended in order to incorporate the increasing cultural, linguistic and globalised societies in which our learners now live (Cazden, et al., 1996; Cope & Kalantzis, 2000).

The *Multiliteracies* approach to pedagogy proposed by New London Group in 1996 will *"enable students to achieve the … twin goals for literacy learning: creating access to the evolving language of work, power, and community, and fostering the critical engagement necessary for them to design their social futures and achieve success through fulfilling employment"* (Cazden, et al., 1996, p. 60). Through the pedagogy of *Multiliteracies*, both teachers and students will be able to recognise that literacy is much broader than the study of language alone. It is dependent on culture and context, and can be remade by language use to suits various purposes (Cope & Kalantzis, 2000).

According to the *Multiliteracies* approach, teachers should concentrate on teaching open-ended and flexible functional grammar in context. This can assist learners to describe the differences between cultural, regional, technical and context-specific language, as well as understand the multimodal ways in which communication happens. For Science classrooms, this could include examining the multimodal ways in which scientist communicate new discoveries in their field and how the interact with current scientific understanding. Using this *Multiliteracies* approach ensures both teachers and learners can actively participate in social change, designing their social future through the way they communicate (Cope & Kalantzis, 2000).

The key elements for developing scientific literacy that were influenced by this framework include:

> *Element 1: Scientific knowledge in its multiple representations*: Students should know enough scientific content and knowledge to distinguish science from non-science, so that they can critically analyse 'science' as it is presented in the media (DeBoer, 2000; Norris & Phillips, 2003).

> *Element 2: Social relevance*: Students need scientific knowledge to intelligently participate in science-based social issues, adapt to a rapidly changing world, function as responsible and informed citizens, and have societal usefulness (DeBoer, 2000; Dillon, 2009; Holbrook, 2010; Holbrook & Rannikmae, 2009; Norris & Phillips, 2003).

These key elements were chosen because if educators can embrace the *Multiliteracies* approach to pedagogy, then Cope & Kalantzis (2000) propose that pedagogy and curriculum can now be by *Design*. Educators should discuss and debate what the design of their pedagogy and curriculum will look like, so that learners can *design* their social futures. This should include discussion on how to create responsible and informed citizens, how to intentionally teach comprehension and evaluation, and what local social issues can be included so that students can directly connect to the society in which they live. *"Teachers… are seen as designers of learning processes and environments… Further, some have argued that education research should be a design science, studying how different curricular, pedagogical, and classroom designs motivate and achieve different sorts of learning. The notion of design connects powerfully to the sort of creative intelligence the best practitioners need in order to be able continually to redesign their activities in the very act of practice"* (Cope & Kalantzis, 2000, p. 20).

To support this discussion on what the design of pedagogy and curriculum should look like, the framework of *Multiliteracies* proposes four integrated factors of literacy learning. These factors are neither hierarchical, nor independent of each other. This pedagogical approach allows for the simultaneous learning of different design factors, and the repeated reviewing of these factors throughout a learner's journey.

The first integrated factor is Situated Practice, which explores the world of the learners' Designed and Designing experiences. It builds ideas that learning should be process driven, and immersed in the learner's society and experiences. Secondly, Overt Instruction allows students to shape an explicit metalanguage of Design that is specific and explicit to them. This factor incorporates pedagogies which explicitly teach rules and conventions of functional grammar (Cope & Kalantzis, 2000).

The third integrated factor of *Multiliteracies* is Critical Framing. Here, learners are taught to relate meaning of language to their social context and purposes. This factor builds on critique and contextualisation pedagogies. Finally, Transformed Practice allows students to transfer and then re-create Designs of meaning from one context to another. For Transformed Practice to occur, pedagogies that relate theory to practice and focus on the transfer of understanding from one context to another must be utilised (Cope & Kalantzis, 2000).

Yelland, Cope and Kalantzis (2008) have utilised the insights of the *Multiliteracies* framework described above to develop a pedagogy based on *knowing in action*, termed *Learning by Design*. This new framework builds on the four integrated factors above, and creates four fundamental ways of knowing: Experiencing; Conceptualising; Analysing; and Applying. These four fundamental ways of knowing, in addition to the insights provided by the *Multiliteracies* framework, are used to inform the key elements for developing scientific literacy proposed by this study, to help determine to what extent scientific literacy is a focus in the *Australian Curriculum: Science* document.

In addition to *Multiliteracies*, *Learning by Design* has been included because it can provide educators with a framework to use when moving from curriculum documents to pedagogy and classroom learning experiences. Therefore, this framework will be used to determine if the integration of Experiencing, Conceptualising, Analysing and Applying is being promoted at the semantic level.

3.2 Critical Discourse Analysis

This research study into the *Australian Curriculum: Science* will focus its methods on CDA. The aim is to discover how scientific literacy has been linguistically positioned within the curriculum document and whether support for its enactment is explicitly or subversively included.

Critical discourse analysis (CDA), while being based on the traditions of language critique, attempts to set up a dialogue between critical social science and linguistics. It begins with the ideas that discourse is an element of social practice, and may both shape and be shaped by other elements of social practice. *"… the basic motivation for critical social science is to contribute to an awareness of what is, how it has come to be, and what it might become, on the basis of which people may be able to make and remake their lives. And this is also the motivation for CDA"* (Chouliaraki & Fairclough, 1999, p. 4). CDA methods place an emphasis on interdisciplinary approaches. This is due to the nature of language construction, and how it functions to transmit knowledge, organise social institutions or exercise power (Wodak & Meyer, 2009).

This social practice view of discourse implies that there is "*a dialectical relationship between a particular discursive event and all the diverse elements of the situation, institution, and social structures which frame it*" (Dijk, 2011, p. 357). For the purposes of this research study, the discursive event is the *Australian Curriculum: Science* document, with the situation, institution and social structures framing this document including the nature of education in Australia at present, the development of a national curriculum by the Australian Curriculum, Assessment and Reporting Authority (ACARA), and the call for Science educators to place a high value on intentional teaching for scientific literacy.

CDA has seven dimensions of discourse studies in common with other fields of discourse/linguistic analysis: "*an interest in the properties of 'naturally occurring language' use...; a focus on larger units* [rather] *than isolated words and sentences…; an extension of linguistics beyond sentence grammar towards a study of action and interaction; the extension of non-verbal… aspects of interaction and communication…; a focus on dynamic (socio)-cognitive or interactional moves and strategies; the study of the functions of… contexts of language use; and an analysis of a vast number of phenomena of text grammar and language use…"* (Wodak & Meyer, 2009, p. 2). However, the main difference between discourse studies and CDA is that CDA studies social phenomena, rather than linguistic units, and therefore requires a more multi-dimensional approach. Language is seen as a social practice, and therefore must be considered in context. The context for this research study is the *Australian Curriculum: Science*, and how scientific literacy is linguistically positioned within this curriculum document.

Due to its problem-orientated, critical approach to research, CDA does not begin with a fixed theoretical or methodological framework. Instead, the CDA approach begins with a research topic or question. From here, the research topic is refined, so that the objective of the research can be pinpointed. A methodology is then chosen, dependent on the topic and research questions being investigated. Therefore, there are a diverse number of research approaches consistent with CDA, and they can draw on any number of linguistic analytical techniques and theories

(Dijk, 2011). For this research study, Fairclough's (2003) CDA method for analysing discourse has been chosen, which is based on textual analysis for social research.

3.2.1 Critical Discourse Analysis methodology

Fairclough's CDA method is based on three main ways that discourse acts as an element of social practice: through genres, discourses and styles. A genre is a way of interacting discoursally, and when investigated can give insight to the social relationships between what is happening both within and surrounding the discourse. Discourses are representations of the world and its social practices, the study of which can give insight into the ideological beliefs behind the language. The style of the discourse is determined by the people involved in its creation, and can give insight into their social identity and personality (Fairclough, 2003).

With these three ways influencing the foundation of the methodology, the following five step process is utilised.

Step 1: Identification of the social problem and context of the document

Step 1 is an exploration into the macro (or big picture) behind the creation of the document. This can include investigations into why there was a need for a national curriculum document, how scientific literacy has been traditionally placed within previous curriculum documents, where its linguistic position is now in this new *Australian Curriculum: Science,* and why there have been calls to increase the scientific literacy of Australian students.

Identification of the social problem surrounding this document will include the linguistic analysis of education policy and curriculum documents leading up to the creation of the *Australian Curriculum:* Science, using a three-pronged approach, investigating:

1. the genre chain of curriculum development, including the Hobart, Adelaide and Melbourne Declarations, as well as the *Statements for Learning for Science*, all of which preceded the *Australian Curriculum: Science* document,

2. the roles and relationships between the stakeholders of the document, and

3. the social events that led to the creation of the document.

Step 2: Identification of obstacles to the social problem

Step 2 investigates the meso and micro levels of the document, and how the discourses and semantic relationships in the document interact to show evidence where scientific literacy is placed within this new *Australian Curriculum: Science*, and how the linguistic positioning of scientific literacy within a curriculum (if it is ambiguous) can cause a lack of scientific literacy development in Australian Science classrooms. This part of the methodology can include an in-depth study of the following linguistic aspects (where appropriate):

1. The type of exchange, to determine whether activity exchange (where teachers are expected to act) or knowledge exchange (where the document is simply providing information) are dominant throughout the curriculum document;

2. The mood of the clauses and sentences, to determine if they are declarative (statements), interrogative (questions) or imperative (commands);

3. The modality of clauses and sentences, to reveal the relationship between the author (ACARA) and readers (education professionals), and

to determine if the modality is epistemic (modality of probabilities) or deontic (modality of obligation);

4. Any assumptions made in the document about science, learning and the future, including any that may show evidence of the *New Learning* framework (where preparing students for the future they may face highly influences curriculum structure);
5. The discourse of science learning, and if science is being presented as an important part of learning and society;
6. If intertextuality is present, demonstrating how other texts and voices may have influenced the document;
7. The semantic relationships between the clauses and sentences, to determine:
    a. the meaning of words, including if active or passive verbs have been used in relation to learners;
    b. if the co-location of words provides particular meanings about scientific literacy and learning;
    c. if propositional or existential assumptions or values about science education and literacy are present;
    d. if lexical chains and patterns of transitivity show evidence of the relationship between science and literacy, and how science in the Australian context is portrayed;
8. If metaphors have been used throughout the document and the significance of these;

9. What values about learning and science have been placed within the document, both explicit evaluative and value assumptions, and how the adjectives used might show evidence of this; and
10. The style or social identity within the text, including how this represents the agency of teachers (as the enactors of the document) and whether scientific literacy is clearly defined or abstract.

Step 3: Who may and/or may not benefit if the social problem changes?

Step 3 will discuss some of the different stakeholders involved in the *Australian Curriculum: Science* document, to determine who may and/or may not benefit from the social problem determined in Step 2 changing.

Step 4: Ways past the problem

Step 4 will examine the key elements for developing scientific literacy described in Chapter 2 and evaluate them against the linguistic discoveries made in the document. From here, a set of recommendations for intentional teaching for scientific literacy will be proposed, so that teachers can be provided with practical advice about how to develop scientific literacy in their students. These recommendations will be based on the key elements for developing scientific literacy described in Section 2.3.

Step 5: Critical reflections on the analysis process

Step 5 will provide insight into the analyst's viewpoints about the analytical process, and any influence that may have had on the outcomes. This section will be written in first person, and demonstrates how the social positioning of the analyst can affect the results.

This use of CDA is a critical factor in the development of this conceptual framework, as it examines the interrelated macro, meso and micro levels within this document to discover how they represent scientific literacy. By using this framework to analyse the *Australian Curriculum: Science* document, the linguistic position of scientific literacy within the text will be determined. The literature reviewed in Chapter 2 clearly stated the importance of intentional teaching for scientific literacy in the classroom. However, if Science educators are not provided with a curriculum document that clearly demonstrates the importance of scientific literacy to the Science learning of students, then its importance can be undermined.

3.3 Summary

Chapter Three began with a recollection of the aim of this investigation: to determine, using critical discourse analysis, what meaning and value has been placed on scientific literacy in the new Australian Curriculum: Science, and how Science educators are expected to respond to this placement of scientific literacy in regards to their intentional teaching for it. From this, Chapter Three explained the theoretical and conceptual frameworks underpinning this investigation, and the methodology used to determine how the new *Australian Curriculum: Science* represents scientific literacy as both concept and pedagogy.

The conceptual framework of this study was displayed graphically in Figure 2. Subsection 3.1.1 then explained how critical social theory is the philosophy that underpins this research investigation. Critical social theory states that learning should not just be the transmission of knowledge; it should be the transformation of knowledge, proposing *"that quality education is as much about teaching students the ability to read the world more critically (ideology critique) as it is imagining a better world that is less oppressive (utopian critique)"* (Leonardo, 2004, p. 16). This investigation proposes that for scientific literacy to develop, Science classrooms should move beyond the transformation of knowledge, into a world where students are able to actively participate in the socio-scientific issues of today and tomorrow.

Subsection 3.1.2 continued explaining the theoretical frameworks underpinning this investigation with a look at the *New Learning* framework, as presented by Kalantzis and Cope (2008). This theory of learning provided ideas for what the future of education could look like, and asks all involved in the education process to examine how the strategies that are used to meet the needs of the current learners are developed, and if those strategies are taking the new social conditions of those learners into account. The four foundational values and principles of *New Learning* were then explored. This study embraces the values and possibilities in *New Learning*, as there is the potential for students to see education as connected to their everyday lives, and proposes that educators examine their pedagogy and beliefs about current education policies and procedures.

The *Multiliteracies* and *Learning by Design* frameworks presented by Cope, Kalantzis and the New London Group were explored in Subsection 3.1.2. These frameworks suggested that traditional ideas of literacy pedagogy need to be extended in order to incorporate the increasing cultural, linguistic and globalised societies in which our learners now live (Cazden, et al., 1996; Cope & Kalantzis, 2000). Eeducators and learners actively participate in social change, interacting on both a local and global stage using social media to design their social future through the way they communicate (Cope & Kalantzis, 2000). Educators should discuss and debate the design of their pedagogy and curriculum, so that learners can *design* their social futures. The four integrated factors of *Multiliteracies* (situated practice, overt instruction, critical framing and transformed practice) were explored, with this investigation concluding that for true *Learning by Design* (with the underlying principles of *Multiliteracies*) to be developed by learners, the curriculum document should acknowledge that traditional literacy strategies that exist outside of the science context may not be enough.

Section 3.2 detailed how CDA will be used in the methodology to discover how scientific literacy has been linguistically positioned within the curriculum document, and whether its enactment is explicitly or subversively included. CDA begins with the idea that discourse is an element of social practice, that discourse may both shape and be shaped by other elements of social practice, and that its methods place an emphasis on interdisciplinary approaches. While CDA has seven dimensions of discourse study in common with other fields of discourse/linguistic analysis, its main focus is the study of social phenomena, and therefore requires a more multi-dimensional approach.

Subsection 3.2.1 detailed the specific methodology chosen for this investigation, based on Fairclough's work on analysing discourse and textual analysis for social research (2003). It involves the use of 5 steps to analyse the macro, meso and micro levels of discourse within the curriculum document. Step 1 involves the identification of the social problem and context of the document. Step 2 identifies obstacles to the problem. Step 3 determines who may and/or may not benefit if the social problem changes. Step 4 describes ways past the problem and provides recommendations for action, with Step 5 allowing the analyst to reflect critically on the analysis process.

By using this framework to analyse the *Australian Curriculum: Science* document, the aim of this investigation will be achieved. In addition, the results of this CDA methodology will allow for recommendations to be proposed for intentional teaching for scientific literacy in Australian classrooms, including ascertaining if the key elements for developing scientific literacy, as described by this investigation in Section 2.3, are accurate. Chapter Four now outlines the results of the analysis performed on the *Australian Curriculum: Science*, and reflects on how the language used linguistically positions scientific literacy within the document.

Chapter 4: RESULTS and ANALYSIS

In this Chapter, results from the critical discourse analysis on the *Australian Curriculum: Science* document will be described and analysed, with links made to the four key elements for developing scientific literacy proposed by this investigation. Section 4.1 begins with identifying the social problem and context of the document, including the context behind the creation of the Australian curriculum, the place of scientific literacy in its development, and how the national curriculum came to be. This section initiates the linguistic analysis with a look at some of the education policy and curriculum documents that came prior to the *Australian Curriculum: Science*, including the Hobart, Adelaide, and Melbourne Declarations, and the *Statement for Learning for Science*. The "continua for scientific literacy", developed by this investigation to help graphically represent the results of the critical discourse analysis, will also be presented and explained in this Section.

Section 4.2 will follow by identifying the obstacles to the social problem, including the results and analysis of steps two and three of the Fairclough CDA method (investigation of the meso and micro levels of the document). Section 4.3 will describe who may and/or may not benefit if the social problem changes, with Section 4.4 detailing ways past the problem. This chapter concludes with Section 4.5 explaining the reflection by the analyst after completing the CDA method, and Section 4.6 provides a summary.

4.1 Identification of the social problem and context of the document

The social problem as determined by this research is that historically, there has been a gap between the intentions of Science Curricula across all States and

Territories to promote scientific literacy, and what actually occurs in the classroom (Hackling, et al., 2001). The incorporation of strategies designed to promote scientific literacy in Science lessons seems to be limited, and this may stem from an ambiguity provided by the curriculum about what scientific literacy is, and its importance to Australian students (Hackling, et al., 2001; Millar, 2006). If Science teachers are to be given the opportunity to value the development of scientific literacy in their students, and allow it to be one of the many foci of their teaching, instead of the current sole focus of the delivery of scientific content and knowledge (Rennie, et al., 2007), then the new Australian Curriculum needs to explicate what scientific literacy is, and how teachers should approach teaching for it.

The implementation of the *Australian Curriculum: Science* in 2012 puts Science educators on the verge of a new chapter in Science teaching, with the opportunity to re-evaluate how science is taught in Australian schools, and what value is being placed on the development of scientific literacy. The aim of this investigation (as stated in Chapter One) is to determine, using critical discourse analysis, what meaning and value has been placed on scientific literacy in the new Australian Curriculum: Science, and how Science educators are expected to respond to this placement of scientific literacy in regards to their intentional teaching for it. Therefore, the social problem that needs to be addressed is whether the *Australian Curriculum: Science* has been designed to promote clearly scientific literacy and the application of this literacy to societal issues, or if there is ambiguity within the document of what scientific literacy is and how it can be taught. This analysis will show if Science educators can gain a clear understanding of scientific literacy from the *Australian Curriculum: Science* document and its importance in the teaching and learning of science.

In addition to understanding the social problem surrounding the development of the *Australian Curriculum: Science*, the discourse of curriculum development is influenced by the context it sits in (Fairclough, Mulderrig, & Wodak, 2011). Therefore, the context of how the *Australian Curriculum: Science* document was developed is significant in understanding how scientific literacy is linguistically positioned within it. Figure 3 below graphically represents the past 25 years of education policy and curriculum development in Australia.

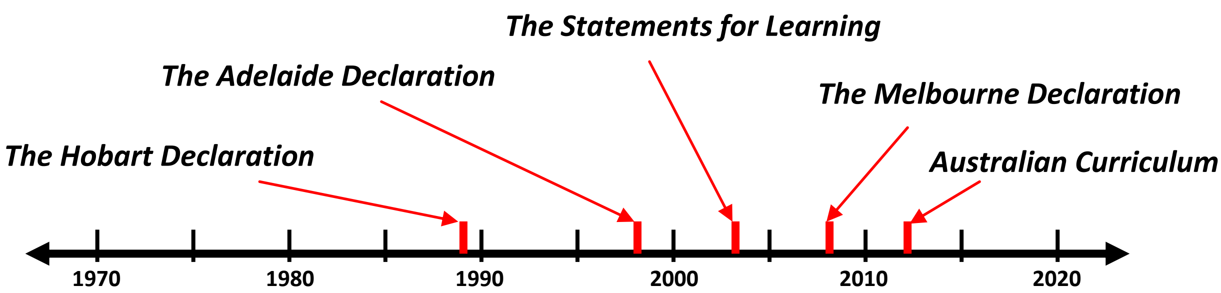


Figure 3: Timeline of education policy and curriculum development in Australia

Sections 4.1.1 through to 4.1.3 below will examine how these different Declarations and Statements for Learning have influenced the development of the Australian Curriculum document, and where scientific literacy has traditionally been placed within education policy and curriculum development. This should provide a starting point for where scientific literacy is linguistically positioned as the new *Australian Curriculum: Science* document is introduced.

To assist with determining the position of scientific literacy in each of the education policy and curriculum documents being investigated (those from the Hobart, Adelaide and Melbourne Declarations, as well as the *Statements for Learning* and *Australian Curriculum: Science*), a system of continua has been developed (as seen in Figure 4 below). These continua represent the four key elements for developing scientific literacy as proposed by this investigation (defined in Section 2.3), and will graphically represent where this investigation believes scientific literacy is linguistically positioned within the each education policy and curriculum development. The continua use a rating system to determine the extent of each scientific literacy element within the document, ranging from 'no statements' present through to 'focused statements' present. The position of each continuum will be determined by the goals of the policy or curriculum, whether relating to the Goals for National Schooling, as detailed in the Hobart, Adelaide and Melbourne Declarations, or the goals outlined in the *Statements for Learning* and *Australian Curriculum: Science* documents. This investigation will use the language and intentions of the goals to determine how much importance the document places on each key element for developing scientific literacy.

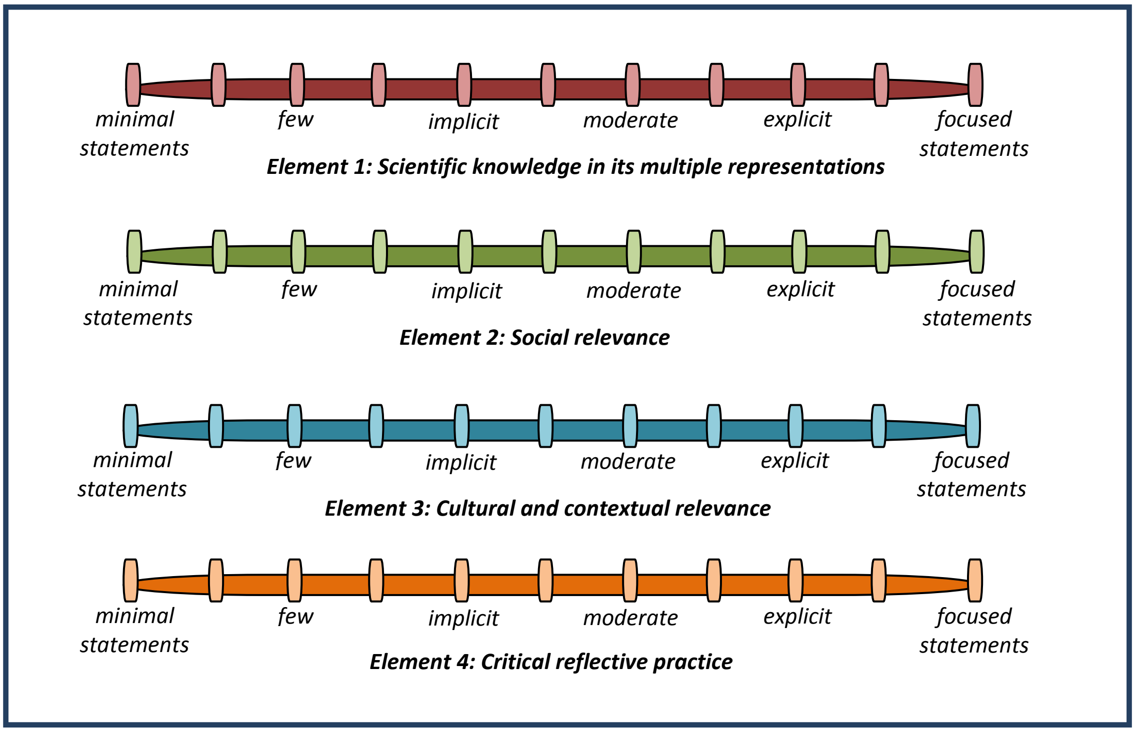


Figure 4: Continua of scientific literacy for analysing curriculum documents

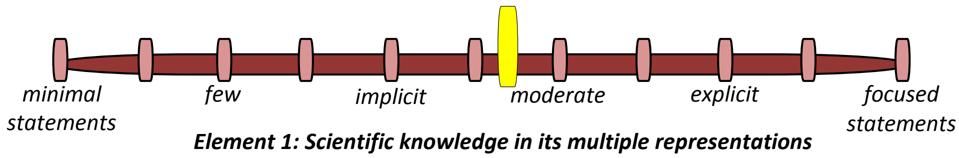
Use of these continua will show how scientific literacy has been linguistically positioned in education policy and curriculum documents over the past 25 years in Australia. It is anticipated that if scientific literacy becomes the focal point for all Science teachers, as this investigation and current literature (Holbrook, 2010; Kolstø, 2001; Millar, 2006; Pouliot, et al., 2010; Rennie, et al., 2007; Tomas, et al., 2011; Yore, et al., 2004) is indicating it should, then the curriculum that teachers follow should more clearly articulate the importance of scientific literacy. This can be demonstrated on these continua, with the four key elements for developing scientific literacy represented as temporally influenced constructs.

4.1.1 The place of scientific literacy in the development of a nationally agreed curriculum

The development of a nationally agreed curriculum for Australia began in 1989 with the Hobart Declaration. Ministers for Education signed off on "Agreed National Goals for Schooling", the aims of which included students developing *"… an understanding of the role of science and technology in society, together with scientific and technological skills; and a capacity to exercise judgement in matter of morality, ethics and social justice"* (MCEECDYA, 1989, p. 1) Students were also expected *"to develop knowledge, skills, attitudes and values which will enable* [them] *to participate as active and informed citizens in our democratic Australian society within an international context"* (MCEECDYA, 1989, p. 1). This national collaboration in education policy and curriculum development meant that the States and Territories agreed to a statement of common principles for key curriculum areas (namely Mathematics, English and Science), and that these principles would identify the key knowledge and skills to which all students were entitled (ACARA, 2010). Although these national goals for schooling were agreed to by the Education Ministers for each State and Territory, they were not compulsory. If government and non-government systems and schools mapped their curriculum against these national agreed goals, and many similarities were found, then it was assumed that the national agreed goals would be used. However, there was no compulsion on the States and Territories to do this, and so no national agreed curriculum was produced (MCEECDYA, 1989).

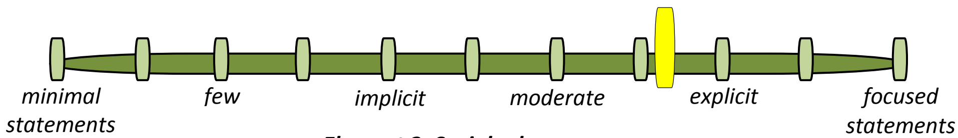
Since these were the first commonly agreed goals for education between the Federal, State and Territory governments of Australia, these "Agreed National Goals for Schooling" can provide a baseline for determining where scientific literacy was initially placed within the focus of the education policy and curriculum. Therefore, the four key elements for developing scientific literacy proposed by this investigation can be used as a multi-dimensional continuum to compare the importance that has been placed on scientific literacy by this Hobart Declaration.

There are ten "Agreed National Goals for Schooling" outlined in the Hobart Declaration. Of these ten goals, Goal Five, "*to provide a foundation for further education and training, in terms of knowledge and skills, respect for learning and positive attitudes for life-long education"* (MCEETYA, 1998, p. 11), and Six (part e), "*an understanding of the role of science and technology in society, together with scientific and technological skills"* (MCEETYA, 1998, p. 11), relate to Key Element One for developing scientific literacy: scientific knowledge in its multiple representations. In this key element, students should know enough science knowledge to be able to differentiate between 'science' and 'non-science' when presented with scientific arguments in the media. This investigation sees the relationship between Goal Five and Key Element One as promising, with the Hobart Declaration stating the importance of knowledge and its application to lifelong learning. It is recognised that this goal discusses knowledge in general, as opposed to scientific knowledge, and so of course curriculum writers have to relate this goal to each of specific subject area. Therefore, the marker on the scientific literacy continuum has been positioned as such to represent that this Key Element is important to the Hobart Declaration, but that the goal does not describe how students need to know enough scientific content to analyse critically information they are presented with by society (and determine the 'science' from 'non-science'). The initial position of scientific literacy Key Element One can be seen below:



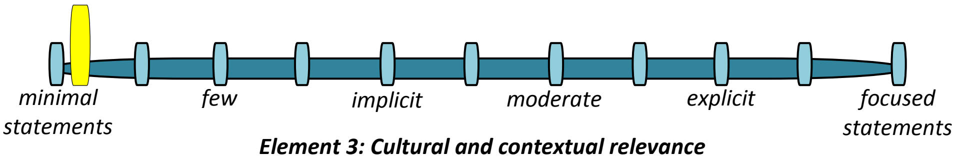
Element 1: Scientific knowledge in its multiple representations

Goal Six (part e) is also specifically about science, and together with Goal Seven, "t*o develop knowledge, skills, attitudes and values which will enable students to participate as active and informed citizens in our democratic Australian society within an international context"* (MCEETYA, 1998, p. 11), relate to Key Element Two for developing scientific literacy, and how students should understand the social relevance of the science knowledge they learn, and develop as informed citizens with societal usefulness. Due to two goals in this Hobart Declaration linking clearly to this Key Element for developing scientific literacy, its initial position can be seen as follows:

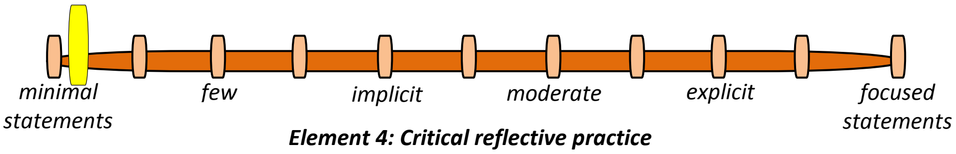


Element 2: Social relevance

Key Elements Three (cultural and contextual relevance) and Four (critical reflective practice) cannot be clearly identified in the ten goals. This is due to the timing of the Hobart Declaration, and how this text (as with all texts) was produced for a specific purpose and should be situated in the context of its time (Apple, 2002; Fairclough, 2003). During the 1980s, cultural and contextual relevance and critical reflective practice may not have been highlighted as important in Science curricula, as the main focus of Science teaching was heavily content-oriented (Goodrum, et al., 2000). Therefore, these two Key Elements are rated as minimal on the continua below:



Element 3: Cultural and contextual relevance



Element 4: Critical reflective practice

Use of the key elements for developing scientific literacy provides this study with the opportunity to determine a starting point for the linguistic position of scientific literacy within the curriculum. As seen by the four continua above, the Hobart Declaration contained language that may not clearly articulate what scientific literacy is, or acknowledge many of what this investigation proposes are the key aspects to it. Consequently, readers of the document may not clearly understand what scientific literacy is. Therefore, based on the language used within the education policy document and the continua of scientific literacies detailed above, the Hobart Declaration does not address the social problem of ambiguity surrounding scientific literacy in education policy and curriculum documents. However, this may be due to the nature of text production and consumption, and how language and text must be studied in light of the social context of when it was produced (Apple, 2002; Fairclough, 2003). Science curricula of the time were mostly content-driven, and did not focus on the development of scientific literacy (Goodrum, et al., 2000). Therefore, in the context of when it was developed, this document probably would not demonstrate the importance of scientific literacy to Australian Science teachers.

Following the development of the “Agreed National Goals for Schooling” being declared at the meeting of Education Ministers in Hobart in 1989, the Curriculum Corporation of Australia was established (MCEECDYA, 1989). This Corporation had a board of management that included nominees of State, Territory and Commonwealth Education Ministers, nominees from the National Catholic Education Commission and National Council of Independent Schools, and could potentially include parents and teachers. The establishment of this Curriculum Corporation of Australia was designed to become the vehicle through which collaborative curriculum development in Australia was to be brought about. However, as with the Agreed National Goals for Schooling, any ‘national curriculum’ document or statements produced were not mandated, with no State or Territory system bound to use them (MCEECDYA, 1989). Therefore, there was probably minimal agreement among the State and Territory education systems with regards to the teaching and learning of science, or the development of scientific literacy for Australian students.

In the wake of the establishment of the Curriculum Corporation of Australia, the Ministerial Council for Education, Employment, Training and Youth Affairs (MCEETYA) was founded in 1994 (MCEECDYA, 2009a). In 1998, this Ministerial Council revised the Agreed National Goals for Schooling, and released the draft ‘Australia’s Common and Agreed Goals for Schooling in the Twenty First Century’, also known as ‘The Adelaide Declaration’. These draft goals aimed to provide real direction for schooling as Australia moved into the 21st Century (ACARA, 2010; MCEETYA, 1998). The release of these goals in draft form also provided, possibly for the first time, key stakeholders in education, including teachers, non-government education sectors, parents and employers, the opportunity to consult on the goals under development (MCEETYA, 1998). This new priority of consultation, and giving agency to other groups to influence education policy and curriculum development (Fairclough, 2003), demonstrated some recognition of the changing nature of education at the time, and that there may have been significant changes socially since the Hobart Declaration (MCEETYA, 1998). Between the Hobart and Adelaide Declarations, the importance of scientific literacy may have increased in Australia, due to an increase in the societal awareness of science (Goodrum, et al., 2000). Therefore, the new 'Goals for Australian Schooling in the Twenty-First Century' had to reflect this new science awareness, and the importance placed on it by society, allowing key stakeholders in society to influence the document's development (MCEETYA, 1998). In addition, this new societal context in which the Adelaide Declaration was developed had to include a sharper focus on student learning outcomes, and therefore the consultation process was also to include an investigation of how targets could be connected to the goals, including the development of standards and benchmarks (MCEETYA, 1998).

Throughout this consultation and investigation process, it was discovered that the main differences between the then current 'Agreed National Goals for Schooling' (from the Hobart Declaration), and the newly developed 'Common and Agreed Goals for Schooling in the Twenty First Century', was not solely concerned with the choice of words or phrases. The new agreed goals were now to include references to how schooling had changed over the decade between 1989 and 1998, and that the emerging priorities of information technology, vocational education, literacy and numeracy, and civics and citizenship were to be emphasised (MCEETYA, 1998). There was also to be recognition of the importance of Aboriginal and Torres Strait Islander perspectives, including the reconciliation process, and the particular learning needs of students from these backgrounds. Again however, these "Common and Agreed Goals for Schooling" were not mandated by the Ministerial Council, and State and Territory governments were only expected to map their current curriculum against them (MCEETYA, 1998).

The Agreed Goals for Schooling in the Twenty First Century were:

1. *Students leaving school should have attained the skills of numeracy and English literacy; in particular, every child leaving primary schools should be numerate, able to read, write, spell and communicate at an appropriate level.*

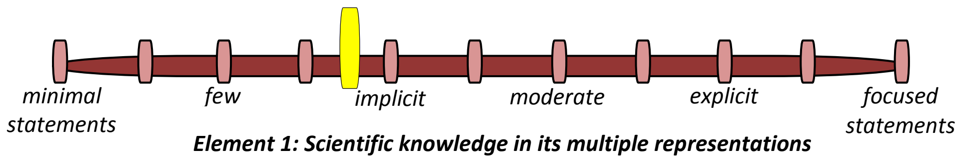
2. *Aboriginal and Torres Strait Islander students should have equitable access, participation and outcomes,* ***and*** *all students should have understanding of and respect for Aboriginal cultures and Torres Strait Islander cultures to achieve reconciliation between Indigenous and non- Indigenous Australians.*

3. *All students should have the knowledge, cultural understandings and skills which respect individuals' freedom to celebrate languages and cultures within a socially cohesive framework of shared values.*

4. *Students leaving school should have a foundation for, and positive attitudes towards, vocational education and training, further education, employment and life-long learning.*

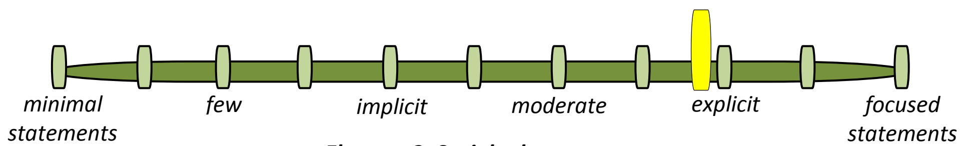
5. *Students should have been encouraged to be enterprising and to acquire those skills which will allow them maximum flexibility and adaptability in the future.* (MCEETYA, 1998, pp. 9-10)

When these new 'Agreed Goals for Schooling in the Twenty First Century' are compared to the four key elements for developing scientific literacy, the following analysis can be made. Initially, there doesn't seem to be any reference to Key Element One for scientific literacy (scientific knowledge in its multiple representations), in any the five goals. A closer look at the notes that accompany these Agreed Goals for Schooling shows some evidence that the document values knowledge and that students should be life-long learners, stating *"students should have attained high standards of knowledge, skills and understanding through a comprehensive and balanced curriculum* (MCEETYA, 1998, p. 7)". However, having this statement in the notes that accompany the goals, and not the goals themselves, can be seen as a backwards step from the goals developed in the Hobart Declaration, where the focus on knowledge was clearly positioned in the goals themselves. Therefore, for this Key Element for developing scientific literacy, the indicator has been moved backwards on the continuum from where it was placed following analysis of the Hobart Declaration, as seen below:



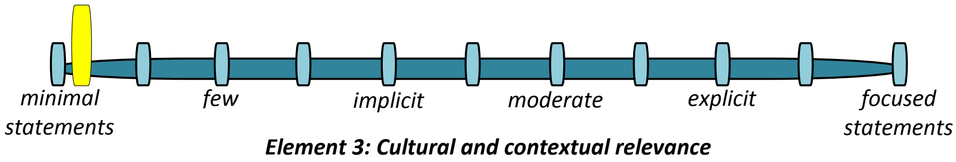
Element 1: Scientific knowledge in its multiple representations

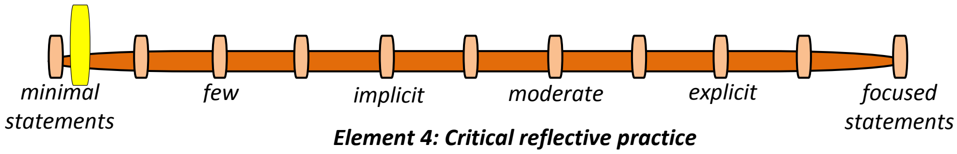
In examining evidence of Key Element Two (social relevance), Goal Three relates to students having an understanding and appreciation of the different cultures that make up a cohesive society. Even though this goal does not make focussed statements that students should make a contribution to society as informed citizens, the notes that accompany these goals do state that students *"… will be enterprising, adaptable and socially responsible contributors…"* (MCEETYA, 1998, p. 7), and that they will be informed and active citizens, that are able to exercise socially responsible judgements that will influence the world around them. With these links to the social relevance that this investigation proposes as necessary for scientific literacy, the indicator for this Key Element for developing scientific literacy can be moved forward on the continuum, to show progress in this element since the Hobart Declaration, as seen below:



Element 2: Social relevance

Key Elements Three and Four cannot be clearly identified in the five goals listed above, and are therefore rated as minimal on the continua below:





From the position of each Key Element for developing scientific literacy on the continua above, it can be determined that the 'National Goals for Schooling' outlined by the Adelaide Declaration have made no noticeable progress towards the development of scientific literacy in Australian students, when compared to the continua for the Hobart Declaration. Therefore, it is concluded that the social problem of ambiguity in key educational documents surrounding the importance of scientific literacy continues to be found in Australian education policy documents that inform curricula.

Following the development of 'Australia's Common and Agreed Goals for Schooling in the Twenty First Century', the Ministerial Council continued to strive for greater national consistency in curriculum outcomes across the States and Territories, and from this endeavour came the *Statements of Learning* in 2003 (MCEECDYA, 2003). These Statements of Learning were to be developed in English, Mathematics, Science, and Civics and Citizenship, and were to be used by State and Territory education departments and curriculum authorities to guide future curriculum development (ACARA, 2010). Again however, these statements were not mandatory, and so States and Territories were under no compulsion to modify their current curriculum to ensure national consistency.

Even though the development of the *Statements of Learning for Science* could be seen as the first step towards a nationally consistent Science curriculum, it was not a curriculum in itself. As with all the *Statements of Learning* developed by MCEECDYA, the documents were established primarily for curriculum developers, and were designed to set out the opportunities for learning that students were to be provided with (Curriculum Corporation, 2006). The production of this document, situated within the societal context of the start of the 21st Century, has a clear focus on scientific endeavours, and acknowledges the heightened societal awareness of science and scientific literacy at the time (Goodrum, et al., 2000). These *Statements of Learning* progressed the argument for the development of scientific literacy, as the *Statement of Learning for Science* detailed how rapid advances in science and technology, and their impact on society and the environment required Science educators to develop students who were scientifically literate (Curriculum Corporation, 2006). These students needed to have *“the capacity to be interested in and understand the world around them, … engage in the discourses of and about science, be sceptical and questioning of claims made by others about scientific matters, be able to identify questions and draw evidence-based conclusions and make informed decisions about the environment and their own health and well-being* (Curriculum Corporation, 2006, p. 2; originally from Goodrum, Hackling, & Rennie, 2000, p. 15).” Such direct instructions to curriculum writers about students engaging with the importance socio-scientific issues around them shows a clear priority for intentional teaching for scientific literacies.

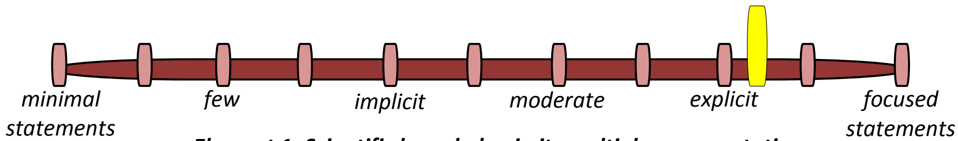
The development of scientifically literate students, as instructed by the *Statement for Learning for Science*, is designed to enable them to be active and informed citizens, who could confidently contribute to the debates about moral, ethical and social issues (related to science), and who could analyse how science and technology shaped society. The education theory set out by this *Statement of Learning for Science* explained how Science education should give students an appreciation of the human aspect of science, and how society has both shaped and been shaped by scientific development (Curriculum Corporation, 2006). Such clear statements about the nature of science, how it relates society, and the need for scientifically literate students is expected in this document. All texts are designed with a purpose and in context (Fairclough, 2003), and the purpose of this document is the improvement of Science education in Australia, at a time when societal awareness of science and scientific literacy was said to have greatly increased (Goodrum, et al., 2000).

In addition to developing scientific literacy, the *Statement of Learning for Science* also sought opportunities for students to:

- *"Use the process of working scientifically, reflection and analysis to investigate and test ideas, refine knowledge and pose new questions;*
- *Develop understanding of the importance of critical thinking, objectivity, logical reasoning and ethical practices in science research;*
- *Use appropriate ways of representing and communicating their science understandings and viewpoints to audiences for a range of different purposes and thereby contribute to and engage in public debate and decision making; and*
- *Acknowledge that aspects of scientific thinking are carried out by all people in different cultural, environmental and economic contexts and that this influences how scientific knowledge develops and is used within those cultures"* (Curriculum Corporation, 2006, p. 3)

This focus on the development of active, informed, reflective learners, who can represent and communicate their science understanding through various discourses, demonstrates the scientific literacy described by the four key elements proposed by this investigation.

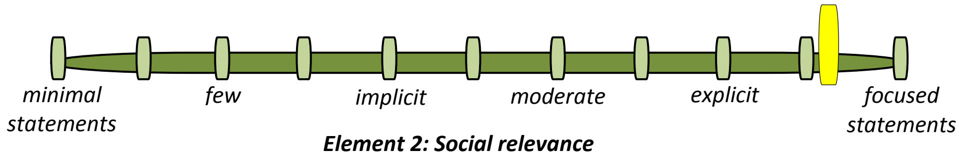
In relation to Key Element One, the *Statements for Learning for Science* details how students need to be sceptical of the science presented to them, especially when it challenges their current understanding of the natural world. To do this, students should have enough science knowledge to differentiate 'science' from 'non-science', which is the basis for Key Element One. In addition to this, the opportunity this document provides for students to understand how scientific knowledge is influenced by cultures, environmental and economic contexts, sees the position of this Key Element on the continuum as 'explicit' below:



Element 1: Scientific knowledge in its multiple representations

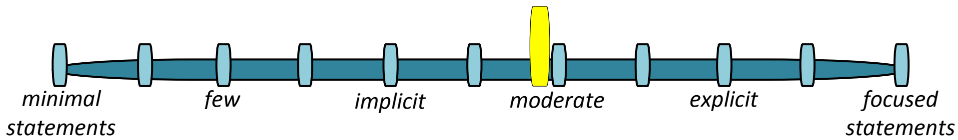
The document also uses language that encourages teachers to provide opportunities for students to engage in public debate on socio-scientific issues. This relates directly to Key Element Two, social relevance. This Element desires students who have societal usefulness and can contribute as responsible citizens. The *Statements for Learning for Science* show an increase in priority for this Key Element when compared to both the Hobart and Adelaide Declarations, with clear statements made by the document about students "*engage*[ing] *in the discourses of and about science"* (Curriculum Corporation, 2006, p. 2; originally from Goodrum, Hackling, & Rennie, 2000, p. 15). Therefore, the continuum for this Key Element of scientific literacy has been moved substantially forward from its position for the

Hobart Declaration, to show how this document is clearly portraying the importance of social relevance to the development of scientific literacy, as seen below:



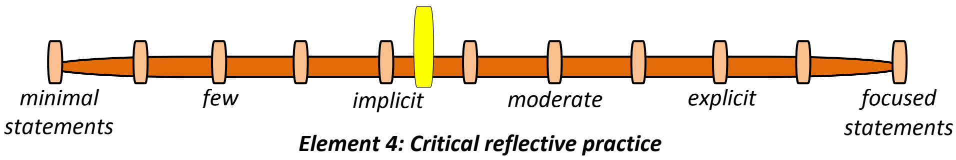
Element 2: Social relevance

Key Element Three has also made progress in this document, when compared to the Hobart and Adelaide Declarations. Statements that discuss how students need to be interested in the world around them, and how they should contribute to and be engaged in public discussions on socio-scientific issues suggests cultural and contextual relevance. Therefore, curriculum writers and teachers could see this as evidence for the need to embed cultural and contextual relevance in Science teaching, including introducing students to the local, national and international issues in society that science provokes, with the hope that as adults they will take an active interest in the science around them and responsibly contribute to society (DeBoer, 2000; Holbrook & Rannikmae, 2007). Therefore, the continuum for Key Element Three indicates forward progression as seen below. However, cultural and contextual relevance can still be seen as ambiguous in this document, as more can be done to ensure the document is clear in its need for teachers to be culturally and contextually relevant in their Science teaching.



Element 3: Cultural and contextual relevance

The need for students to develop critical reflective practice in the development of scientific literacy has been alluded to, yet not prioritised in the *Statement of Learning for Science*. The view of scientific literacy evident in this document has made progress from both the Hobart and Adelaide Declarations, with mention of reflection included in the opportunities for students described above. However, reflection is collocated with scientific investigations, suggesting a superficial view of reflection is to be considered, which does not satisfactorily address Key Element Four for developing scientific literacy. For critical reflective practice to be incorporated into Australian Science classrooms, promoting the development of students as reflective citizens, students should be provided with the opportunity to reflect on how their preconceived ideas and beliefs influence their learning of science (Norris & Phillips, 2003), and not solely reflect on how their scientific investigations were conducted. Therefore, this continuum can indicate a move forward for critical reflective practice, as seen below. However, it does require a more critical elaboration of reflection for a focused priority.



Element 4: Critical reflective practice

From the results of these ratings on the key elements continua above, it can be seen that progress has been made in this document towards prioritising the development of scientific literacy in Australian students. There is clarity about some of the key elements for developing scientific literacy, and some of the uncertainty around scientific literacy in this document has been addressed. Therefore, it can be concluded that due to the macro context in which this document was produced (Fairclough, 2003), when an increase in societal awareness of science and scientific literacy was seen (Goodrum, et al., 2000), the *Statement for Learning for Science* has attempted to tackle the social problem of ambiguity in education policy and curriculum documents around scientific literacy, and this is promising. It is this focus on scientific literacy development and lack of ambiguity, first incorporated into this *Statement of Learning for Science*, which this research aims to explore in the new *Australian Curriculum: Science* of 2012.

4.1.2 The beginnings of a national curriculum

At the MCEETYA meeting in 2005, the Education Ministers re-confirmed the original purpose of the *Statements of Learning* and requested that new *Statements* were developed for additional curriculum areas. In addition, the first step towards a nationally consistent curriculum was taken, when MCEETYA endorsed a process for the State and Territory education jurisdictions to comply with the *Australian Government Schools Assistance Act 2004*, on the implementation of the *Statements of Learning* (MCEECDYA, 2003). This Act decreed that all Australian States and Territories implement curriculum that incorporated the *Statements of Learning* by the 1st of January 2008 (Australian Government, 2004). With this implementation of the Statements of Learning came the introduction of the National Assessment Program in Literacy and Numeracy (NAPLAN). This National Assessment Program was designed to assess the learning of Australian students in a nationally consistent fashion, and was based on the *Statements of Learning* of English and Mathematics (ACARA, 2010). However, with a national assessment program that focuses on the *Statement of Learning for English*, and uses this as the backbone for a 'literacy' test, then the linguistic position of 'English literacy' can be seen to be elevated as the key to literacy development in students. This could indicate a devaluing of the literacies of other subjects, including the scientific literacy detailed in the *Statement of Learning for Science*.

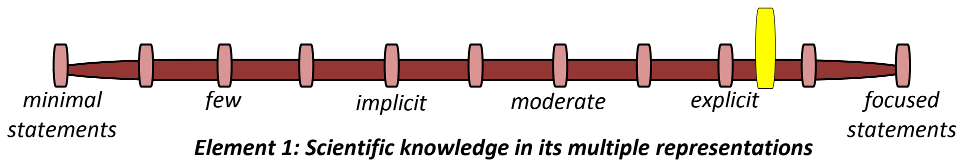
In December of 2008, MCEETYA released the 'Melbourne Declaration for Educational Goals for Young Australians'. This Declaration superseded the Adelaide Declaration, and was aimed at acknowledging the major changes in the world since 1998, and how these changes place new demands on education. A key factor in the development for this new Declaration was need for Australia to engage with new scientific concepts and principles in a problem-solving and creative approach, to ensure the future for all Australians (MCEETYA, 2008). The Melbourne Declaration reduced the ten ‘Common and Agreed Goals’ outlined in the Adelaide Declaration to just two: “*Australian schooling promotes equity and excellence”* and *“All young Australians become successful learners, confident and creative individuals, and active and informed citizens”* (MCEETYA, 2008, pp. 7 - 8). The new Declaration for Education Goals also included the development of “A Commitment to Action”, to promote world-class curriculum and assessment, and an “Action Plan”, commencing from 2009 (MCEETYA, 2008).

The inclusion of an Action Plan to accompany the Declaration for Educational Goals outlined how the Australian Government, and the States and Territories would work together to ensure the declaration was enacted. This included:

- *“The National Education Agreement;*
- *The Schools Assistance Act 2008, which confirms the Australian Government’s financial support for the non-government school sector;*
- *The National Partnership Agreement on Literacy and Numeracy;*
- *The National Partnership Agreement on Low Socio-economic Status School Communities;*
- *The National Partnership Agreement on Improving Teacher Quality; and*
- *Other National Partnerships that may be agreed during the life of this plan* (MCEECDYA, 2009b, p. 3).”

The reduction of the multiple goals previously listed in both the Hobart and Adelaide Declarations, and the *Statements for Learning*, to just the two listed in the Melbourne Declaration, could be pre-emptively seen as a backward step for scientific literacy. However, it could also be argued that the purpose of this document is to be overarching, and to allow elaboration on the goals by each subject area, therefore they have deliberately been left broad. This is evidenced by a priority on discipline knowledge during the development of this document, with clearly defined curriculum areas, and a focus on how the changing nature of society and the new demands placed on Australian education affect curriculum knowledge (MCEETYA, 2008). The notes that accompany these two goals in the Melbourne Declaration show evidence of this, with an indication that specific science knowledge and scientific literacy skills are important to this new phase of learning in Australian schools (MCEETYA, 2008).

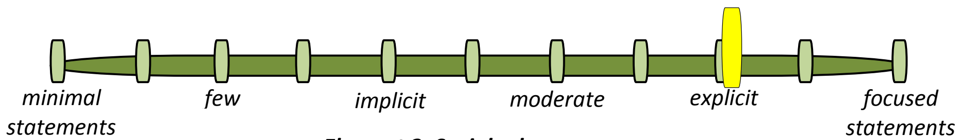
When the Melbourne Declaration is compared to the continua for the key elements for developing scientific literacy, the following results can be seen. For Key Element One, where scientific content and knowledge is highly valued, the notes that accompany the Melbourne Declaration goals state that students should develop their capacity to learn, think deeply and logically, explore the evidence that is available to make informed decisions, and develop as lifelong learners that should continue on a path to further education and training (MCEETYA, 2008). These notes demonstrate that a curriculum based on these goals should value knowledge, so that students can become informed citizens. Therefore, the continuum for Key Element One for scientific literacy can be maintained at its explicit level (as placed there from the *Statements for Learning*), as seen below:



Element 1: Scientific knowledge in its multiple representations

Key Element Two, highlighting the importance of social relevance and striving for students to have societal usefulness, was well developed in the *Statements for*

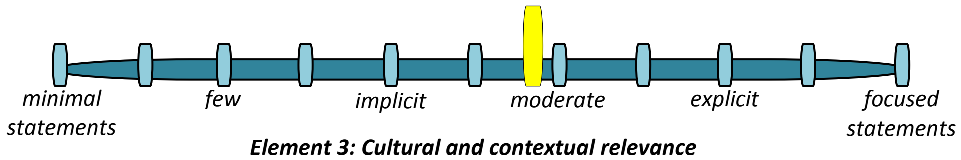
Learning. The Melbourne Declaration has continued with this trend, with the second goal of *"All young Australians become successful learners, confident and creative individuals, and active and informed citizens"* (MCEETYA, 2008, p. 8). Also included were notes indicating that students need to develop as responsible global citizens that work for the 'common good' and are able to act with moral and ethical responsibility (MCEETYA, 2008). This is a continuation of the social relevance desired by the *Statements for Learning* curriculum developed in 2003. However, there is some lack of explicitness to the notes provided in the Melbourne Declaration. It is also noteworthy that the discussion surrounding the discourses of science has been removed, prompting criticisms from some that this new curriculum is 'dumbed-down' and too concerned with being 'politically-correct' (Donnelly, 2011). Therefore, whilst the rating for this Key Element can be maintained at a high level for the Melbourne Declaration, it should be moved backwards, as seen below, to indicate how the *Statement for Learning for Science* was more explicit in its acknowledgement of this Key Element for developing scientific literacy.



Element 2: Social relevance

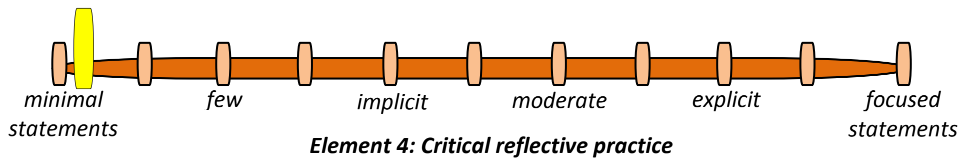
As seen in the Hobart and Adelaide Declarations, Key Elements Three and Four can be perceived to be struggling to gain attention in the goals for national schooling, with limited identification of the need for cultural and contextual relevance, and the desire for students to develop critical reflective practices. The *Statements for Learning* in 2003 altered this trend, with improvements in these Key Elements (as seen by the improved rating on the continua). When analysing the Melbourne Declaration and its two goals for national schooling, there is a backward trend, similar to the Hobart and Adelaide Declarations, in these Key Elements once again.

The Melbourne Declaration shows some evidence of Key Element Three in the notes that accompany the national goals for schooling. Key Element Three highlights the importance of cultural and contextual relevance to scientific learning, and how students need to understand the relevance of science to oneself, to culture and to their community. This could be seen in a curriculum document as teachers provided with the freedom to investigate the societal issues that directly relate to their students. The Melbourne Declaration includes statements that demonstrate its valuing of cultural and contextual relevance. The notes provided for Goal One: *"Australian schooling promotes equity and excellence"* (MCEETYA, 2008, p. 7) include references to schooling being influenced by parents and the wider community, and that learning should contribute to a *"social cohesive society"* (MCEETYA, 2008, p. 7). The notes that supplement Goal Two also include that students should participate in civic life in Australia, and that they are local as well as global citizens (MCEETYA, 2008). In addition to this, the "Commitment to Action" plan that accompanies these goals includes detailed information on how parents and local communities should contribute to the schooling of Australian students. This section of the Melbourne Declaration outlines how it is important that all Australians work together to ensure students develop as responsible adults who contribute to their local community (MCEETYA, 2008). Such references to the contributions that the community and parents make to the education of Australian students shows a desire for greater transparency from the government, with regards to the goals for schooling in Australia, and how parents may now expect greater power in relation to their child's education and can be viewed as key stakeholders in the development of school curricula (Donnelly, 2009, 2012). Therefore, the goals outlined in the Melbourne Declaration (and their accompanying notes and action plans) can be seen to emphasize the importance of cultural and contextual relevance to the learning of Australian students. This can be translated to the continuum depicted below, where the value of Key Element Three as shown from the *Statements for Learning* can be maintained.



Element 3: Cultural and contextual relevance

Key Element Four, critical reflective practice, can again be seen as overlooked in the goals for national schooling as described in the Melbourne Declaration. There is minimal mention in the goals (or the notes that accompany them) that students should reflect on what they are learning in the classroom or develop as reflective citizens. Again, the idea that previously held beliefs and opinions influence the learning that occurs in the classroom is neglected. Such critical reflective practices are important to students becoming aware of how they can be influenced by the world around them, and therefore should have a higher status in the national goals for schooling than what has been presented by the Melbourne Declaration. Therefore, as indicated on the continuum below, this Key Element for developing scientific literacy has been moved back to its original starting place as per the Hobart and Adelaide Declarations, because the Melbourne Declaration shows little evidence of valuing critical reflective practice as an important factor in the development of scientific literacy.



Element 4: Critical reflective practice

With the positions of the four continua from the Melbourne Declaration shown above, it can be concluded that, although the curriculum documents based on these goals should be explicit in their detailing of the importance of some of the key elements for developing scientific literacy (namely Elements One and Two), Elements Three and Four have not been prioritised. Such evidence suggests further ambiguity in Australian education policy and curriculum documents when discussing scientific literacy. Therefore, the Melbourne Declaration can be seen to contribute to the social problem highlighted by this investigation, that is, the uncertainty and lack of clarity around scientific literacy in Australian classrooms. For this social problem to be tackled, the new *Australian Curriculum: Science*, which is based on this Melbourne Declaration (ACARA, 2012a), needs to overcome the current positions of Key Elements Three and Four for scientific literacy, and provide teachers with clearer requirements for how they can promote scientific literacy in their classrooms.

4.1.3 ACARA and the Australian Curriculum

In addition to the notes and the Commitment to Action plan that accompanies the Melbourne Declaration, the "Action Plan for the Melbourne Declaration for Educational Goals" also included the establishment of the Australian Curriculum, Assessment and Reporting Authority (ACARA). This new curriculum authority was tasked with delivering

> "*key national reforms in curriculum and assessment including: development of a rigorous, world-class national curriculum,… starting with national curriculum in the key learning areas of English, mathematics, the sciences and history to be implement in all jurisdictions and sectors from 2011;… development of plans to improve the capacity of schools to assess student performance, and to link assessment to the national curriculum where appropriate; and management of the National Assessment Program…"*
>
> (MCEECDYA, 2009b, pp. 14 - 15).

ACARA is under the direct supervision of MCEETYA, who is responsible for determining the extent of ACARA's work in curriculum and assessment, and who makes key decisions in relation to the development and implementation of the national curriculum.

The Australian Curriculum, Assessment and Reporting Authority (ACARA) began the journey to a national curriculum in 2008 as the National Curriculum Board (NCB) (ACARA, 2010). Initially, the NCB began by scoping the State and Territory curriculum frameworks to audit current curriculum practices. By the end of 2008, work had begun on framing papers in English, Mathematics, Science and History, and public consultation was undertaken to determine the shape of the new curriculum (Interim National Curriculum Board, 2008). In 2009, the NCB reformed to become the ACARA Board, including representatives from every State and Territory education department and curriculum authority, representatives from the Catholic education system and the Independent Schools sector. This new ACARA Board released the Overarching Shape of the Australian Curriculum papers in English, Mathematics, Science and History (ACARA, 2010), and these new shaping papers were said to include feedback from the 2008 framing papers (National Curriculum Board, 2008). These new papers were again released to key stakeholders for consultation, before drafting of the curriculum began at the end of 2009 for English, Mathematics, Science and History. However, there is no discussion of who these ‘key stakeholders’ were in the consultation process, and no details provided by ACARA to the extent to which their ‘feedback’ was adopted and incorporated into the curriculum development process.

The development of the Australian Curriculum had four phases, as seen in Figure 5 below (ACARA, 2012d):

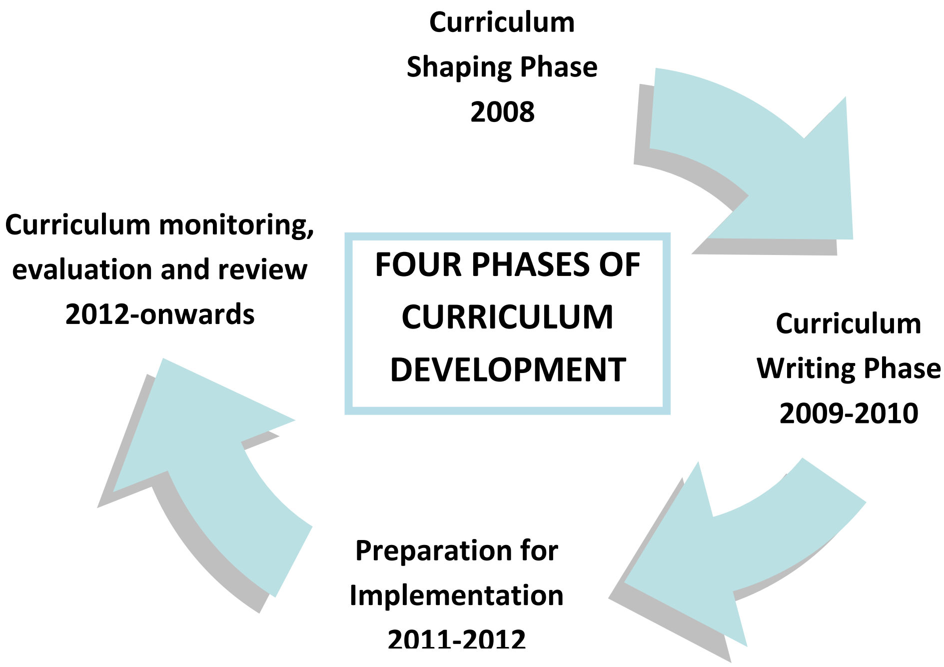


Figure 5: Key phases in the development of the Australian Curriculum: Science

The first phase is the Curriculum Shaping Phase provided the broad outline for each learning area from Foundation to Year 10 (F – 10). This phase included the development of Shape papers and Curriculum Design papers, and these papers provided direction to the curriculum writers and were open to public consultation. This phase was undertaken in 2008. The second phase was the Curriculum Writing Phase (from 2009 – 2010), where teams of writers, advisory panels and ACARA curriculum staff developed the Australian Curriculum. At this stage, the current State and Territory curricula, as well as international curriculum and assessment were used as reference points, and the draft Australian Curriculum was again released for consultation. However, ACARA does not mention which international countries' curricula were consulted, or how much of an influence these international countries had on the development of any Australian Curriculum documents.

The Preparation for Implementation Phase was the next stage, where school authorities and schools had access to the curriculum online. ACARA worked with the State and Territory authorities to support the implementation of the Australian Curriculum; however it was up to the States and Territories as to how they went about the implementation. This phase started in 2011, and continued in 2012. The final phase, the Monitoring and Evaluation Phase, is where monitoring and review processes are coordinated by ACARA, and it is likely to begin after 2012 (ACARA, 2012d).

During the development of the F – 10 curricula, there have been detailed descriptions of the number of formal consultations processes undertaken. These included: public online access where individual or group feedback could be submitted; consultations forums in each State and Territory; National consultation forums attended by teachers and curriculum experts; trial school activities in 150 schools across the country; detailed curriculum mapping activities to assess similarities and differences to current curriculum; written submissions from schools, curriculum authorities and professional associations; presentations and workshops run by ACARA to raise awareness of curriculum development; and public awareness campaigns in the media, asking for public involvement in the design of the new Australian Curriculum (ACARA, 2010; National Curriculum Board, 2008).

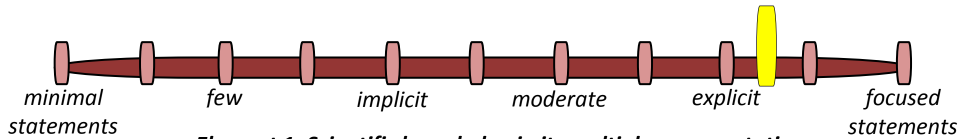
In addition to these consultation processes, the Equity and Diversity Advisory Group was established to provide advice on equity and diversity perspectives to ACARA at key stages in the curriculum development process (ACARA, 2012c). Moreover, 50 schools were chosen by ACARA to participate in an intensive engagement process with the draft curriculum. These schools were chosen to represent the Australian schooling populace, and included schools in rural, remote and metropolitan areas: from Independent, Catholic and government schooling systems; covering low, medium and high socioeconomic status; and representing Aboriginal and Torres Strait Islander, English as an Additional Language or Dialect (EAL/D) and students with disability (ACARA, 2012c). These extensive draft papers, feedback forums and consultation opportunities were designed to include key stakeholders in the development of the new curriculum. From this, it can be ascertained that ACARA considered the key stakeholders in the development of the Australian curriculum to include: the Australian Government; State and Territory Governments; education authorities of each State and Territory; schools and schooling boards; curriculum writers and experts; researchers in educational practice; and teachers, parents and students. Again however, there are no details provided by ACARA as to how much of a voice each of these key stakeholders had in the development of the new curriculum, or if each voice was equally heard.

The development of the Australian Curriculum by ACARA is guided by the Melbourne Declaration, and aims to design a curriculum for the 21st century, with a focus on knowledge, understanding and skills (ACARA, 2012a). This curriculum describes the learning entitlement for each Australian student, and is designed to inform the content that all young people should be taught, and the achievement standards expected at different points throughout their schooling. However, the Australian Curriculum also acknowledges the skill sets, behaviours and dispositions that will apply across the disciplines and content areas, and that students will need to become life-long learners in this globalised and information-rich world (ACARA, 2012a, 2012c). In addition to these general capabilities and cross-curriculum priorities, the Australian Curriculum recognises that young people have different needs and interests, and that their learning styles will vary, both now and into the future, so it is said to be designed to allow teachers to reflect the local cultures and contexts of their students (ACARA, 2012e). Moreover, the curriculum is said to be designed to remain dynamic and responsive to the changes in society and educational practices of the future, and so feedback from its use and developments in educational research are said to be taken into account as the years progress (ACARA, 2011a, 2011b).

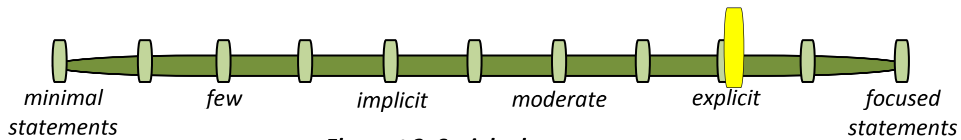
The "Shape of the Australian Curriculum" paper describes the rationale for introducing a national curriculum as *"improving the quality, equity and transparency of Australian's education system"* (ACARA, 2011b, p. 5). It also describes how changes in society over the period from the Hobart Declaration into 1989 to the Melbourne Declaration in 2008 need to be reflected in educational practices, including: new global integration and international mobility; Australia needing to become 'Asia literate' (due to the growing influence of India, China and other Asian nations); rapidly advancing technological changes demanding improved skill sets; and complex social, economic and environmental pressures requiring the use of scientific concepts and principles to develop new and creative problem solving techniques (ACARA, 2011b). This "Shape" paper also notes how the new curriculum has been benchmarked against curricula from leading nations around the world. However, again there is no mention of which international countries these are, or how much of the curriculum has been designed to suit these 'leading nations' (ACARA, 2011b, 2012c). It could be predicted that this international pressure to compete in the global knowledge economy and use scientific concepts and principles to be technologically innovative (Goodrum, et al., 2000; MCEETYA, 2008) is prioritising the development of the *Australian Curriculum: Science* over other curriculum subjects, placing it in the first round of curriculum development and implementation.

The Australian Curriculum states a priority for literacy and numeracy development from the early years of schooling through to the first years of lower secondary schooling, however it acknowledges the importance of learning literacy and numeracy skills across different learning areas (ACARA, 2011b). Each curriculum document provides the intended audience (namely teachers) with the rationale, aims, curriculum content and achievement standards for a particular learning area. This describes what teachers are expected to teach and what students are expected to learn across the first 11 years of schooling (ACARA, 2011b, 2012c). There is emphasis placed on the knowledge, skills and understanding expected of students in each learning area for each year level; however teachers are said to be able to choose how to introduce the concepts and processes to their students. Schools and education authorities are also given the scope to decide how best to deliver the curriculum and are allowed to offer additional learning opportunities outside the Australian Curriculum, if it suits the needs of their students (ACARA, 2011b).

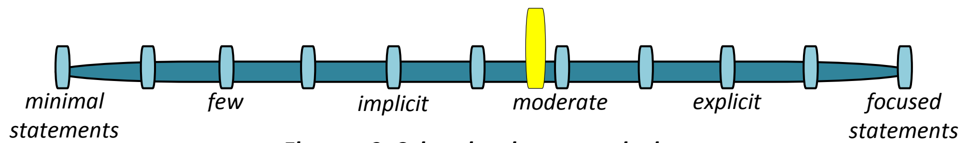
In conclusion, from the above description into how the Australian Curriculum was developed and the context in which it is placed, the starting positions of the four key elements for developing scientific literacy proposed by this study can be seen below:



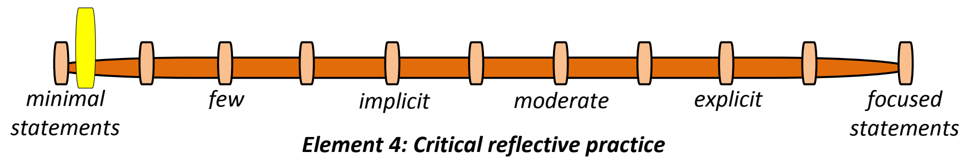
Element 1: Scientific knowledge in its multiple representations



Element 2: Social relevance



Element 3: Cultural and contextual relevance



Element 4: Critical reflective practice

It is from this starting position that this investigation now begins to look at the meso and micro levels of the *Australian Curriculum: Science* document, to discover how scientific literacy is linguistically positioned within this new curriculum. Following the completion of the meso and micro analysis, these four continua will again be used to determine if this curriculum document is highlighting the importance of scientific literacy to teachers and students, and if progress has been made from this starting point. So far, the comparisons of the Declarations and national goals that preceded this curriculum document have shown evidence that curriculum documents and national goals are vague on many of the key elements for developing scientific literacy as proposed by this investigation. It is hoped that the new *Australian Curriculum: Science* does not follow this current trend, or the social problem of ambiguity in education policy and curriculum documents (when it comes to scientific literacy) will continue.

4.2 Identification of obstacles to the social problem

Textual analysis gives an account of the choices the text makes to portray its point of view to the reader (Chouliaraki & Fairclough, 1999). This section of the chapter will investigate the meso and micro levels of the *Australian Curriculum: Science*, and how the text, discourses and semantic relationships in the document interact to show evidence of whether and how scientific literacy is being prioritised in the document. It will also explore how teachers are represented as the enactors of the document, and if the presentation of scientific literacy is clear.

After the initial macro analysis of the broader context of the document (as outlined in Section 4.1), and an initial examination of the curriculum document, the following linguistic aspects were determined to be most appropriate to this study:

1. The type of exchange, to determine whether activity exchange (where teachers are expected to act) or knowledge exchange (where the document is simply providing information) are dominant throughout the curriculum document;
2. The mood of the clauses and sentences, to determine if they are declarative (statements), interrogative (questions) or imperative (commands);
3. The modality of clauses and sentences, to reveal the relationship between the author (ACARA) and readers (education professionals), and to determine if the modality is epistemic (modality of probabilities) or deontic (modality of obligation);
4. Any assumptions made in the document about science, learning and the future;
5. The discourse of science learning, and if science is being presented as an important part of learning and society;
6. What values about learning and science have been placed within the document, both explicit evaluative and value assumptions, and how the adjectives used might show evidence of this; and
7. The style or social identity within the text, including how this represents the agency of teachers (as the enactors of the document) and whether scientific literacy is clearly defined or abstract.

To assist with determining how scientific literacy is portrayed, the key elements for developing scientific literacy (as described in Section 2.3) will again be used as guiding posts for the discussion of the linguistic aspects of this study. The four key elements for developing scientific literacy proposed by this study are influenced by both critical social theory and critical pedagogy (Bayne, 2009; Carrington & Selva, 2010; Giroux, 2004; Leonardo, 2004; McLaren & Houston, 2004; McLaughlin, 1999):

> *Element 1: Scientific knowledge in its multiple representations*: Students should know enough scientific content and knowledge to distinguish science from non-science, so that they can critically analyse 'science' as it is presented in the media (DeBoer, 2000; Norris & Phillips, 2003).
>
> *Element 2: Social relevance*: Students need scientific knowledge to intelligently participate in science-based social issues, adapt to a rapidly changing world, function as responsible and informed citizens, and have societal usefulness (DeBoer, 2000; Dillon, 2009; Holbrook, 2010; Holbrook & Rannikmae, 2009; Norris & Phillips, 2003).
>
> *Element 3: Cultural and contextual relevance:* Students should understand the relevance of science to oneself, to culture and to their community (DeBoer, 2000; Holbrook & Rannikmae, 2007).
>
> *Element 4: Critical reflective practice*: Students can develop reflective practices, examining how the science knowledge presented influences their own beliefs and pre-conceived ideas, and if the information presented has strong-enough evidence to challenge those ideas (Norris & Phillips, 2003), in an effort to develop as reflective citizens.

This research investigation aims to determine if the *Australian Curriculum: Science* is promoting scientific literacy, by valuing the key elements for developing scientific literacy outlined above, or the transmission of scientific content and knowledge, which has been traditionally prioritised in Science curricula (Goodrum, et al., 2000). If these four key elements for developing scientific literacy are valued within the document, then this investigation should see an improvement in each continuum of scientific literacy used in Section 4.1. In addition to this, if there are improvements made in the explicitness of scientific literacy within this document, then the social problem of ambiguity within the curriculum document should be reduced.

4.2.1 Meso Analysis – The structure of the Australian Curriculum: Science document

To begin, an analysis of the meso level of the document will be undertaken, to investigate the contextual specificities of the *Australian Curriculum: Science* document, and how the discourse of a curriculum document is situated in regards to other discourse moments (Chouliaraki & Fairclough, 1999; Ryan & Bourke, 2012). In particular, this analysis will investigate how the design specifications for the *Australian Curriculum: Science* document are outlined in the Curriculum Design Paper that accompanies it (ACARA, 2012b). This additional resource outlines the structure and function of the many different parts of the curriculum, including the rationale, aims, organisation, curriculum content and achievement standards. This investigation will now briefly explain each of these parts, to ensure an overall picture of the meso level of this analysis is achieved.

The first 17 introductory pages of the *Australian Curriculum: Science* document outline the main foci of the curriculum. The document begins with a rationale that provides teachers and students with reasons why the included content is important, and to what extent certain aspects of content will be investigated (ACARA, 2012b). In this rationale there is also mention of the organisation of this content, so that teachers can see a holistic approach to the learning that is to occur from Foundation to Year 10. The rationale is no more than 200 words, and is used to clarify the ‘big ideas’ of the content area, ensuring an understanding of what the curriculum writers have deemed to be the essential knowledge to be taught (ACARA, 2012b). It is then followed by the aims of the learning area, and these are written in bullet point form (not as a numbered list) to identify what major learning students will undertake throughout the curriculum. For the *Australian Curriculum: Science* there are seven aims and these aims will be examined in more detail in Section 4.2.3 below.

The Organisation section of the document provides an overview of how the curriculum is structured, and includes both a summary of the content covered and descriptions of what the curriculum sees as the nature of the learner (ACARA, 2012b). For the *Australian Curriculum: Science*, there are three interrelated strands of Science Understanding, Science as a Human Endeavour, and Science Inquiry Skills. The Science Understanding strand then comprises four sub-strands, including Biological Sciences, Chemical Sciences, Earth and Space Sciences, and Physical Sciences. The document gives a brief paragraph overview of the content that is to be included in each of these four sub-strands (Australian Curriculum, 2011).

The Science as a Human Endeavour strand is explained in an opening paragraph, and then its two sub-strands, Nature and Development of Science, and Use and Influence of Science are clarified using one sentence overviews (Australian Curriculum, 2011). Even though these few sentences appear to lack detail, when compared to the extensive descriptions provided for each of the Science Understanding sub-strands, the two major reasons for this may relate to firstly, the curriculum writers' understanding of the nature of the reader, and secondly, the increased focus on disciplinary knowledge across the curriculum as a whole (Freebody, et al., 2008). First, Science teachers have traditionally seen themselves as deliverers of science knowledge or content (Alvermann, et al., 2011; Hanrahan, 2009; Rennie, et al., 2007). Therefore, the intended reader of this document, the Science teacher, can be assumed to be more interested in what scientific content is to be taught, and not the other strands or sub-strands involved. Secondly, Science curricula have traditionally been heavy in science content, focussed on multidisciplinary knowledge (Freebody, et al., 2008; Goodrum, et al., 2000). This view can be encouraged by scientists desiring volumes of content in their disciplines to be taught, and by a society that prioritises scientific ways of knowing, seeing it as dominant over non-scientific discourses (Ninnes, 2001).

This could be confirmed when analysing the Science Understanding sub-strands, with the evidence being the detailed paragraphs used to explain the content that is to be covered over the 11 years the curriculum spans. It could be interpreted that the curriculum document is introducing the Science as a Human Endeavour strand to the Science teacher as a different concept from what is traditionally thought of as important Science learning, and it is doing so in a subtle manner. This can indicate the document prioritising disciplinary knowledge, as traditional Science curriculum documents have done (Goodrum, et al., 2000), with the space given to the disciplinary knowledge section of the document indicative of the value placed on it by curriculum writers (Fairclough, 2003). The literature indicates that Science as a Human Endeavour is key to the development of scientific literacy, as it focuses on the dynamic processes of science and what humans do with, for, and in the name of science, rather than on static knowledge (Holbrook, 2010; Norris & Phillips, 2003; Tomas, et al., 2011). Thus, in future, this strand could replace Science Understanding as the key framing feature of the curriculum document, as a way to begin addressing the social problem of ambiguity towards scientific literacy in Australian curriculum documents.

The curriculum document then goes on to explain the Science Inquiry Skills strand with a paragraph, and follows this with one sentence explanations of each of its five sub-strands: Questioning and predicting, Planning and conducting, Processing and analysing data and information, Evaluating, and Communicating (Australian Curriculum, 2011). It can be seen that again, these sub-strands contain less information or explanation than the sub-strands in Science Understanding. However, unlike the Science as a Human Endeavour strand that may be new to Science teachers, Science Inquiry Skills have always been seen as important in Science learning (Fang & Wei, 2010), and so the curriculum writers may have assumed that Science teachers are familiar with these sub-strands already. It should be recognised however, that the space given to this strand in the document can indicate its reduced priority, when compared with the Science Understanding strand.

The *Australian Curriculum: Science* document follows the descriptions of the three key strands with a brief explanation of the inclusion of Year Level Descriptions, Content Descriptions and Content Elaborations. The Curriculum Design Paper that accompanies this document explains how each Content Description and Elaboration has been written with an implicit stem (ACARA, 2012b). When reading descriptions and elaborations throughout the bulk of the document (pages 18 through 74), each one appears to be a declarative statement with low modality, for example *"Energy from a variety of sources can be used to generate electricity"* (Australian Curriculum, 2011, p. 41) comes from the Year Six Science Understanding strand. It is accompanied by the Content Elaboration *"investigating the use of solar panels"* (Australian Curriculum, 2011, p. 41). Each of these declarative statements shown above seems to be a statement with no initial implication that the reader needs to act on it.

However, each Content Description and Elaboration should be read in light of the implicit stems detailed in the Curriculum Design Paper, where *"Students will be taught…"* (for Content Descriptions) and *"This may involve students…."* (for Content Elaborations) (ACARA, 2012b, p. 21). Such an implicit stem can be concluded as a key factor of this and every curriculum document. Even though their meso structure appears on the surface to be that of knowledge exchange, the simple provision of information from writer to reader, curriculum documents are in fact full of activity exchange (Fairclough, 2003) and high modality statements. It is intended that the readers, assumed to be teachers, are to act on the information provided throughout the document. Such an implicit stem is not included in the explanation of the Content Descriptions and Elaborations provided in the introductory section of the document. This can show how the meso structure of a curriculum documents includes the propositional assumption (Fairclough, 2003) that the reader understands their place in the curriculum process. They are seen as the enactors of the document, without being explicitly told.

The succinct explanations of the Content Descriptions and Elaborations are followed by an outline of the six Overarching Ideas of the curriculum, what the curriculum focus of each year level is, and an explanation of the purpose of Achievement Standards at the end of each year level. The final seven pages of the introductory section then overview the Diversity of Learners that teachers might encounter, and the General Capabilities and Cross-Curriculum Priorities. These pages demonstrate the existential assumptions (Fairclough, 2003) that: there will be diverse learners in every classroom, and these students need to be catered for; schools should be preparing students as productive citizens by ensuring they develop capabilities outside of specific curriculum areas; and all curriculum areas are linked by overarching priorities that satisfy the goals of national schooling in Australia (MCEETYA, 2008). This acknowledgement of diverse learners can be seen as encouraging, and links clearly with the *New Learning* framework that underpins this study (Cope & Kalantzis, 2000). There is also a small section on how this Science curriculum relates to other learning areas (namely English, Mathematics and History), and the Implications for teaching, assessment and reporting (Australian Curriculum, 2011). The subsequent pages of the *Australian Curriculum: Science* document (pages 18 through 74) detail the content that is to be taught from

Foundation to Year 10, broken in Year Levels, Strands and Sub-Strands. Each Year Level finishes with an Achievement Standard that clearly articulates what the students should know by the end of that year, showing evidence of propositional assumptions about what will be, and value assumptions about what is desirable and good (Fairclough, 2003).

This brief outline of the meso level of the document aims to demonstrates the knowledge exchange (Fairclough, 2003) structure that is inherent in all curriculum documents. The document's purpose, on the surface, is to provide clear information about what is to be taught to Australian Science students, to its readers, Science teachers. However, the use of implicit stems throughout the bulk of the document can make visible its underlying and more dominant purpose, that of an activity exchange document where readers are required to act upon the information. This investigation will now delve deeper into the linguistic aspects of the *Australian Curriculum: Science*, and examine how the specific language used in this curriculum document portrays the development of scientific literacy. If there is ambiguity in the curriculum document, with no clear direction of what scientific literacy is and how it could be developed in students, then the social problem identified by this investigation will persist. For this social problem to be overcome, this micro analysis of the document should discover language use that clearly articulates what scientific literacy is, why its development is important, and how readers are to ensure its inclusion into their everyday Science teaching.

4.2.2 Micro Analysis – Element 1: Scientific knowledge in its multiple representations

To grasp the nature of science and how it is both influenced by and in turn influences society, students should know enough scientific content and knowledge to distinguish science from non-science, so that they can critically analyse ‘science’ as it is presented in the media (DeBoer, 2000; Norris & Phillips, 2003).

The *Australian Curriculum: Science* details a range of scientific content and knowledge that is to be taught to all Australian students from Foundation to Year 10. This delivery of content knowledge from curriculum writers to teachers could initially be seen as ‘knowledge exchange’ (Fairclough, 2003), where the document is providing information to the reader. Examples of this are seen with clauses to define the strands and sub-strands of the content structure, for example *“The biological sciences sub-strand is concerned with ….”* (Australian Curriculum, 2011, p. 4). Such clauses demonstrate the document providing knowledge information to the reader, particularly in regard to what is meant by terms the reader will come across throughout the document. This can allow for a common understanding of terms by both the document writer and reader. Such clauses are also found to define the other sub-strands of the Science Understanding strand, including Chemical Science, Earth and Space Sciences and Physical Sciences. In addition, further knowledge exchange could be seen by the use of clauses such as *“Science inquiry involves…”* (Australian Curriculum, 2011, p. 5) and *“Science investigations are…”* (Australian Curriculum, 2011, p. 5), again where the document writer is establishing a common understanding of terms used throughout the document.

The use of knowledge exchange statements is also evident throughout the curriculum pages of the document. These pages detail the content knowledge that is to be taught to the students, so it can be expected that knowledge exchange would be evident. The purpose of a curriculum document is to tell teachers what scientific content is important for students to know, as outlined in the meso level analysis sub-section above. In doing so, the document is providing information about those aspects of science knowledge that have priority in Australian schools (Goodrum, et al., 2000).

However, such use of knowledge exchange clauses, as detailed above, can provide insight into one of the many underlying assumptions this document makes about the reader, and the scientific content that is to be delivered. Firstly, this document suggests the propositional assumption (Fairclough, 2003) that the reader will agree with what is being presented, particularly in regards to it setting up a common understanding of terms. As seen in the examples described above, *"Science inquiry involves…"* (Australian Curriculum, 2011, p. 5) and *"Science investigations are…"* (Australian Curriculum, 2011, p. 5), these two statements show evidence of the document telling teachers what these terms mean, and apparently allowing no opportunity to disagree or to provide alternative definitions.

Such an assumption of agreement can also be observed when the document provides declarative statements about how students learn. This can be seen throughout the entire document, particularly in the first 17 pages that describe how the curriculum is organised, and also in the introductory statements of each year level. For example, from The Overarching Ideas section that details the framework of the curriculum: *"As students progress from Foundation to Year 10, they are building skills and understanding that will help them to observe and describe patterns…, and develop and use classifications to organise events… As students progress…, they become more proficient…..Student increasingly recognise…"* (Australian Curriculum, 2011, p. 7). Such use of the term "students" or "they", in the Theme position of a sentence describing what the students are about to do or learn, is found 66 times in the first 17 pages, and includes verb variations such as: "students can, develop, are, investigate, classify, recognise, view, gain, progress, understand, explore, learn, think, observe, infer, being, describe, and appreciate".

Such use of these verbs can indicate to the reader that this is how a student learns, and this makes the assumption that the reader agrees. There can be little to no debate about how students learn, and there does not seem to be the opportunity for the reader (namely teachers) to put forward their point of view about the nature of learning and how students develop understanding of scientific concepts and ideas. This apparent lack of debate reinforces the view of teachers as the unquestioning supporters and implementers of curricula and pedagogy, with a limited authoritative voice in curriculum decisions (Ryan & Bourke, 2012; Thomas, 2005).

This assumption can also be evident in how the document describes the relationship between Science and other subject areas. For example: *"Learning in Science involves the use of knowledge and skills learnt in other areas, particularly in English, Mathematics and History"* (Australian Curriculum, 2011, p. 16). Such a statement leads to the assumption that the reader understands the links between Science and other subjects at school, and posits that Science learning is not independent of learning in other subjects. This position apparently taken by the curriculum, to link Science learning with skills learnt in English, Mathematics and History, is supported by literature, and is important to the development of scientific literacy. Yore, et al. (2003) state that *"language is an integral part of science and scientific literacy"* (p. 691), and that students should be exposed to language types from various sources and on various subjects. In fact, the link between Science and English, and the differentiation between English literacies and Science literacies could be even more explicit in the curriculum document, to provide teachers with an awareness of their responsibilities to teach literacy within the science context. Science teachers do not see themselves as teachers of English language literacy, believing that this is the job of the English teacher (Alvermann, et al., 2011; Hanrahan, 2009; Norris & Phillips, 2003). This belief should be overcome, if teachers are to embrace teaching for scientific literacy in their classrooms.

Therefore, even though the document shows evidence of a relationship between Science and other subjects, and does so in a manner that assumes the reader agrees, more could be done to ensure Science teachers recognise the vital relationship between the learning of language and ways of consuming, producing and representing knowledge in both Science and English. This example, where the curriculum does not seem to take the opportunity to be more explicit on a traditionally misunderstood aspect of scientific literacy, can be seen to continue the social problem of ambiguity within the document.

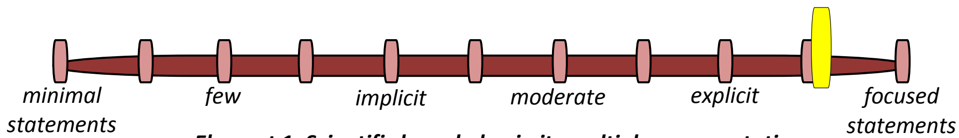
In addition, the clauses about the nature of how students learn are written in timeless present tense (Fairclough, 2009). There is no evidence of statements like "students will understand", "students might increasingly recognise" or "students may develop". This lack of future-oriented present tense and modal adverbs to suggest uncertainty in statements can provide the reader with a viewpoint that this is how all students learn throughout their schooling. There is limited opportunity for readers to disagree with the document, or suggest that students may not learn in the way that is described. If the document had used future-oriented present tense, stating that "students <u>may</u> develop" a certain understanding, then readers are given the opportunity by the curriculum writers to propose alternatives, for example "due to certain circumstances, students <u>may not</u> develop". Therefore, without this opportunity to challenge the expectations set by the document about how students learn, readers of the document can be expected to accept that this is the nature of student learning, and that if the document is followed, this is the teaching outcome. Such expectations set by the document do not appear to cater for the diverse nature of students, and that all students come to science with different socio-cultural contexts that will influence the way they learn (Goodrum, et al., 2000). This propositional assumption of how students learn, and the timeless present tense used to make this assumption, could be due to the meso structure of the document (Fairclough, 2009). As a curriculum document, it is traditional that knowledge exchange occurs between the author and reader. If this document were to give readers the opportunity to question the information presented, then it may fail in its purpose, which is to provide consistent information for Science teachers throughout Australia.

This apparent assumption of agreement is clearest when investigating the scientific content to be delivered during each year and the relative achievement standard to be gained by the student. The content is seemingly outlined in declarative statements, demonstrating the knowledge to be taught, with the addition of Elaboration statements if further clarification is required. For example, in the content described for Year 3, the Science Understanding content includes: *"Living things can be grouped on the basis of observable features and can be distinguished from non-living things"* (Australian Curriculum, 2011, p. 27), with the Elaborations including *"recognising characteristics of living things such as growing, moving sensitivity and reproducing"* (Australian Curriculum, 2011, p. 27). The Achievement Standard for this Year level then describes *"They* [students] *describe features common to living things."* (Australian Curriculum, 2011, p. 29). These statements can be analysed as activity exchange masquerading as knowledge exchange, with the underlying assumption the reader should agree with both the content as it is presented, and the nature of how the students will learn it. Thus, the curriculum can be seen as positing the overarching assumption that 'this is how it will be in every Science classroom in Australia'. Such an assumption is often made by a curriculum document, to ensure continuity and consistency from classroom to classroom. If declarative statements were not used in this way, without an underlying assumption of agreement and in future-oriented tense (for example: *"Students might develop an understanding of characteristics of living things at some point during Year 3…"*), then the curriculum document may not serve its purpose to state clearly what scientific content is to be taught.

Research has shown that traditionally, Science teachers see themselves as a deliverer of scientific content (Bybee, 2009; Dillon, 2009; Holbrook & Rannikmae, 2009). Therefore, these declarative statements providing information on what is to be taught to students could be seen as the most important part of the curriculum for many Science teachers, because scientific content is traditionally highly valued. However, Science teachers should be encouraged to let go of this apparent need to disseminate scientific content to their students (Holbrook, 2010; Yore, et al., 2004), and embrace the first key element for developing scientific literacy. This element focuses not on the volume of content that is to be taught, but that the content is 'enough' to ensure students can differentiate between 'science' and 'non-science' when it is presented to them. In previous studies on Australian curriculum documents, Rennie and Goodrum (2007) describe how many of these curricula contain disproportionate amounts of content, and that this may hamper the efforts of teachers to provide engaging science lessons. In this curriculum, the linguistic evidence can lead to the conclusion that the volume of scientific content to be covered is not excessive, and satisfies the requirements of the first key element for developing scientific literacy. This conclusion is based on the way the curriculum content has been designed, with very general Content Descriptions detailing the mandatory science concepts that are to be covered. Science concepts written in this very broad, general manner seem to differ from previous curriculum documents in Australia.

One comparison that could be made, for example, to the Queensland and New South Wales curriculum document prior to the introduction of the *Australian Curriculum: Science*. These documents seem to contain more mandatory knowledge concepts to be covered per year level. In Year Nine for example, the Queensland Essential Learnings curriculum contained 17 different science concepts in the *Knowledge and Understanding* strand (QSA, 2007), whilst the New South Wales Science Year Nine Curriculum contained 21 different *Domain: Knowledge and Understanding* concepts (Board of Studies New South Wales, 2012). In the new *Australian Curriculum: Science*, the equivalent Science Understanding strand seems to only contain seven science concepts to be taught (Australian Curriculum, 2011). This example could be used to show evidence of a significant reduction in the amount of scientific content to be covered, and can support the first key element proposed by this investigation, that science students should know 'enough' scientific content, and that the focus of the curriculum could shift from scientific content-driven to scientific literacy-driven.

In conclusion, when gauging where this first key element for developing scientific literacy stands in this new *Australian Curriculum: Science*, in comparison to its place in the Melbourne Declaration, the indicator can be moved forwards to the focused end of the continuum.



Element 1: Scientific knowledge in its multiple representations

The position on the continuum is not at the highest point, because the clarity surrounding the mandatory nature of the Content Descriptions could be improved. Since it is common for a reader to internalise other discourse moments (beliefs and values) whilst reading a text (Chouliaraki & Fairclough, 1999), the inclusion of the Content Elaborations within the document may be misinterpreted by teachers as being mandatory, because they are traditionally accustomed to every part of a curriculum document being compulsory. For this key element to be included by Science teachers in their teaching practice, one more step could be taken, and that is to limit the weight given to the Content Elaborations when studying the curriculum. One suggestion could even be that these non-mandatory parts of the curriculum, that exist as helpful suggestions and options, could be contained within an additional 'resources' document for teachers to consult as they felt necessary. If this were to occur, the *Australian Curriculum: Science* document would assist with the first key element for developing scientific literacy proposed by this investigation. As a consequence, progress towards overcoming the social problem of ambiguity within curriculum documents about the nature of scientific literacy could occur.

4.2.3 Micro Analysis – Element 2: Social relevance

This investigation suggests that for students to become scientifically literate, they need scientific knowledge to participate intelligently in science-based social issues, adapt to a rapidly changing world, function as responsible and informed citizens and have societal usefulness (DeBoer, 2000; Dillon, 2009; Holbrook, 2010; Holbrook & Rannikmae, 2009; Norris & Phillips, 2003).

Evidence of the social relevance of science can be seen in the discourse of science learning throughout the document. The document begins with the Rationale and Aims of the *Australian Curriculum: Science*. The second sentence of this rationale states *"The knowledge it* [science] *produces has proved to be a reliable basis for action in our personal, social and economic lives."* (Australian Curriculum, 2011, p. 3). Such a statement in the first paragraph of the document can indicate the document's existential assumption (Chouliaraki & Fairclough, 1999) that science is important to our social and economic lives.

In addition to this opening paragraph, one of the seven Aims of the *Australian Curriculum: Science* is *"an ability to solve problems and make informed, evidence-based decisions about current and future applications of science while taking into* *account ethical and social implications of decisions"* (Australian Curriculum, 2011, p. 3). This aim can be seen to outline the implications of the relationship between science and society, and having a curriculum where students can see the social relevance of the science concepts they are learning is one important factor in the development of scientific literacy (Holbrook, 2010; Norris & Phillips, 2003). Furthermore, even though the aims of the curriculum are listed as bullet points and not in numerical order, grammatically, in keeping with the Theme positioning (Halliday & Matthiessen, 2004), they could be read as being listed in order of importance. The aim described above, that directly links to the importance of science to society, is listed before the aim for students to have a solid foundation of knowledge in the scientific disciplines (Australian Curriculum, 2011). This can imply that the curriculum document values the social relevance of science at least as much as (if not more than) the traditional scientific content and knowledge. With this value on social relevance being noticeably positioned within the aims of the document, this could be evidence that this curriculum is trying to reduce the ambiguity of scientific literacy in previous curricula, and may even be attempting to overcome the social problem of Science teachers being unclear about scientific literacy and its importance.

Moreover, if the aims of the *Australian Curriculum: Science* are read in importance from the first bullet point down, in keeping with Theme positioning detailed above (Halliday & Matthiessen, 2004), students develop *"an interest in science", "an understanding of the vision that science provides", "an understanding of the nature of scientific inquiry", an ability to communicate scientific understanding", "an ability to solve problems",* and *"an understanding of historical and cultural contributions to science"* before the document mentions *"a solid foundation of knowledge"* (Australian Curriculum, 2011, p. 3). It is noteworthy that the "knowledge" part of learning science, which for so long has traditionally dominated Science curricula (Rennie, et al., 2007), is placed 'last' in the list of aims for this curriculum. It can be seen to be 'superseded' by interest, vision, communication, and historical and cultural awareness. Such an apparent importance placed on students developing an interest in science, and how it relates to the development of society around them (through the vision it gives them and their ability to understand its methods of inquiry and communication) can provide evidence of this curriculum document outlining the importance of teaching science in a way that links directly to its social relevance. Holbrook and Rannikmae (2009), along with DeBoer (2000), highlight this importance of students fostering an appreciation of science, and suggest that this is fundamental to the development of scientific literacy.

This apparent 'rearrangement' of the priorities of Science teaching, to one that now highlights interests, inquiry and social relevance, might be seen as a deliberate linguistic technique used by the writers of the new *Australian Curriculum: Science* to promote the focus of Science teachers shifting away from traditional knowledge delivery. This linguistic positioning by the writers of this curriculum could direct teachers to re-evaluate their position on the importance of *how much and how* scientific content is explored in the Science classroom. These aims can be an indicator that the curriculum document is attempting to overcome the social problem that seems to have been maintained in Australian Science curriculum documents so far, where scientific literacy can be concluded to be ambiguous, and where Science teachers seem to fail to recognise its importance. This step towards the promotion of the social relevance of science at the start of the curriculum document, and the seemingly 'lower priority' of the traditionally held view of the importance of scientific content and knowledge, can be seen as promising for the development of scientific literacy, and will be reflected in the continuum for Key Element Two for developing scientific literacy proposed by this investigation.

Additional evidence of the importance placed on the social relevance of science by this document can include how the discourse of science seems to permeate through the Science as a Human Endeavour strand. In its initial description of Science as a Human Endeavour, the document states *"Science influences society by posing, and responding to, social and ethical questions, and scientific research is itself influenced by the needs and priorities of society."* (Australian Curriculum, 2011, p. 5). This can be concluded as a clear link to the social relevance of science, and, written in such a declarative way, the reader can be assumed to agree with it (as with the other knowledge exchange clauses and statements described).

It can also be concluded that the clearest evidence of this document valuing the social relevance of science (and in turn that science should be taught in a socially relevant way) is seen in the Science as a Human Endeavour strand in each of the year level content descriptions. Although there seems to be limited evidence in the Foundation to Year Three descriptions (which could be explained by students of these year levels assumed to have limited maturity to understand the concept), the main discourse of science being socially relevant seems to become clearer in Year Four. One of the Science as a Human Endeavour sub-stands, Use and Influence of Science, lists a Content Descriptor as *"Science knowledge helps people to understand the effect of their actions"* (Australian Curriculum, 2011, p. 32). It then includes Content Elaborations that detail *"investigating how a range of people… use science…"* and *"explore how science has contributed to a discussion of an issue…"* (Australian Curriculum, 2011, p. 32). Evidence that even further seems to solidify the importance of the social relevance of science, and how both it is influenced by and in turn influences society, is in the Achievement Standard for this year level. It states *"They* [students] *describe situations where science understanding can influence their own and others' actions."* (Australian Curriculum, 2011, p. 34). By placing the Content Description into the Achievement Standard of the document, writers of the curriculum could be seen as confident that it will be taught, and that students should be given the opportunity to see the social relevance of the science they are learning, as teachers highly value and focus on assessment and demonstrating what students have achieved (Goodrum, et al., 2000).

More examples of this discourse of science and its relationship to social relevance can be seen through Year levels Five to Ten, with each year level adding more complexity and depth to the relationship (as can be expected by the increase in the maturity of the students). Year Five includes *“Scientific understanding, discoveries and inventions are used to solve problems that directly affect peoples’ lives”* (Australian Curriculum, 2011, p. 37), with Year Six including *“Scientific knowledge is used to inform personal and community decisions”* (Australian Curriculum, 2011, p. 42). Again, both of these year levels are seen to have Achievement Standards that include statements where students are expected to describe and explain how scientific knowledge has been used to inform social decision making (Australian Curriculum, 2011). This apparent acknowledgement of the importance of teaching students to appreciate the significant role science plays in today’s society will hopefully promote the second key element for developing scientific literacy, where students need to become responsible and useful citizens (Holbrook, 2010; Norris & Phillips, 2003).

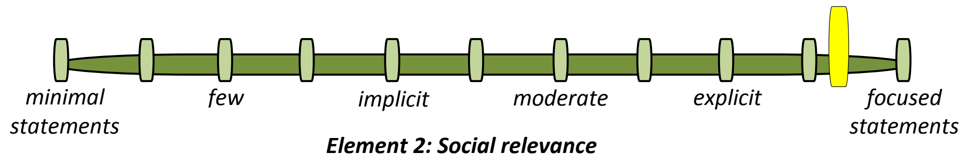
From Year Seven, students should be required to understand how scientific knowledge changes over time, and that this knowledge is developed through the collaboration of many people (Australian Curriculum, 2011). Importantly, Year Seven is seen to introduce students to the importance of social, cultural and ethical implications of science, with the Content Elaboration of one Science as a Human Endeavour Content Description including *“recognising that the solution of some questions and problems requires consideration of social, cultural, economic or moral aspects rather than or as well as scientific investigation.”* (Australian Curriculum, 2011, p. 48). DeBoer's (2000) position on scientific literacy suggests the need for students to understand the cultural implications of science, and describes how science could be viewed as "*a cultural force in the modern world (p. 591)."* In addition to this, the relationship between science and society seems to be become stronger in the Year Eight description, stating *"Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical consideration"* (Australian Curriculum, 2011, p. 53). This relationship between science and technology, and their influence on society and the development of scientific literacy in students is well documented (Holbrook, 2010). Therefore, these 'Science as a Human Endeavour' statements that seem to highlight the strong relationship between science, technology and society can make good progress towards promoting the development of scientific literacy in Australian students.

Further, this investigation sees the strongest indication that the discourse, and therefore importance, of science and its relationship to society is highly valued within this document can be found in the Year Ten description. All five of the Content Descriptors for the Science as a Human Endeavour strand can be seen to link directly to students developing an understanding of how science and society are related, and these descriptions show evidence of aiming to prepare students who have the scientific knowledge to participate intelligently in science-based social issues, adapt to a rapidly changing world, function as responsible and informed citizens and have societal usefulness (DeBoer, 2000; Dillon, 2009; Holbrook, 2010; Holbrook & Rannikmae, 2009; Norris & Phillips, 2003). These descriptions include *"Scientific understanding… is contestable and… refined over time"*, *"Advances in scientific understanding often rely on developments in technology…"*, *"People can use scientific knowledge to evaluate whether they should accept claims, explanations or evidence"*, *"describing how science is used in the media…"*, *"using knowledge of science to test claims made in advertising"*, *"Advances in science… can* *significantly affect people's lives..", "The value and needs of contemporary society can influence the focus of scientific research"*, and *"recognising that financial backing from governments or commercial organisations is required for scientific developments and that this can determine what research is carried out"* (Australian Curriculum, 2011, pp. 65-67). Such content descriptions show evidence of a clear emphasis on students arguing and debating ethics and funding, analysing data and evidence, and using critical thinking and problem solving techniques, all of which are suggested by the literature as important to the development of scientific literacy (Millar, 2006; Pouliot, et al., 2010; Tomas, et al., 2011; Yore, et al., 2004).

In addition to this evidence found in the Science as a Human Endeavour strand, there is also evidence of this theme of science and society throughout the Year Ten Science Inquiry Skills descriptions. Here, students are asked to *"Critically analyse the validity of information…"*, including *"researching the methods used by scientists in studies reported in the media"*, *"judging the validity of science-related media reports and how these reports might be interpreted by the public"*, and *"describing how scientific arguments, as well as ethical, economic and social arguments, are used to make decisions regarding personal and community issues"* (Australian Curriculum, 2011, p. 68). The importance of these scientific concepts, both within the Science as a Human Endeavour strand, and Science Inquiry Skills, is solidified in the Achievement Standard for Year Ten. This Achievement Statement attempts to ensure students use evaluation and critical analysis techniques to determine the validity of both the evidence presented in scientific theories, and the evidence presented by secondary sources, which is suggested as an important factor in developing scientific literacy (Yore, et al., 2004). Such focus on the relationship between society and science is proposed by this investigation as a key element for the development of scientific literacy. So, with such declarative and deontic modality (Fairclough, 2003) statements constructed, these Science as a Human

Endeavour Content Descriptions are of great importance to the teaching and learning of science under the *Australian Curriculum: Science*.

Therefore, with this document seeming to present explicit statements as evidence of the importance that science has in society, both within the Science as a Human Endeavour and Science Inquiry Skills stands, readers of the document will hopefully acknowledge that teaching the social relevance of science is vital to students understanding the nature of scientific discovery and developing scientific literacy. In conclusion, the new position of this key element for developing scientific literacy on the continuum can be seen below:



Element 2: Social relevance

In this element, the *Australian Curriculum: Science* seems to excel at bringing the social relevance of science to the forefront, and as such, the importance of this aspect of scientific literacy. The examples explained above provide evidence to teachers of this key element for developing scientific literacy, and in doing so allow a clearer picture of scientific literacy to be developed. This can be concluded as demonstrated progress towards overcoming the social problem of scientific literacy being ambiguous in Australian curricula.

4.2.4 Micro Analysis – Element 3: Cultural and contextual relevance

For scientific literacy to develop, this investigation proposes that students should understand the relevance of science to oneself, to culture and to their community(DeBoer, 2000; Holbrook & Rannikmae, 2007). To assist with this, the curriculum should allow teachers the freedom to investigate any social issues that are paramount to their students and their community. In sections 4.2.2 and 4.2.3 above, this investigation has concluded that a large proportion of this curriculum document includes declarative statements that endeavour to provide knowledge exchange between the document and the reader. In addition to this, it has also been explained how these statements may be underpinned by the assumptions of activity exchange and imperative (commanding) statements, linguistic aspects that a curriculum document traditionally contains. However, there is also evidence within the document of teachers being given the freedom to investigate any social issues that are paramount to their students, and this can be seen with the inclusion of epistemic statements (statements that are weaker in modality, and are therefore more of a 'probability' rather than an 'obligation'). Examples of these statements, particularly in regards to the freedom given to teachers to include cultural and contextual relevance, are examined below.

The aim of the curriculum includes the statement that students should develop *"an understanding of…contemporary science issues…"* (Australian Curriculum, 2011, p. 3), and the description of the Science Understanding strand explains how it *"…will inform students' understanding of contemporary issues…"* (Australian Curriculum, 2011, p. 6). Additional statements about the cultural and contextual relevance of science can also be seen in the curriculum focus of Years Seven to Ten, where teachers are seemingly directed that *"It is important to include contemporary contexts in which a richer understanding of science can be enhanced* (Australian Curriculum, 2011)." The inclusion of the term 'contemporary' in both the aims of the curriculum, and the description of the Science Understanding strand, could indicate the need for cultural and contextual relevance in the presentation of scientific content. The document also tries to make certain the term is not misinterpreted by readers, with the glossary at the back of the document providing a definition of *"Contemporary Science: new and emerging science research and issues of current relevance and interest* (Australian Curriculum, 2011, p. 70)*."*

Furthermore, use of the term important in the curriculum foci of Years Seven to Ten can be seen as the document attempting to guarantee the reader is clear on the need to follow this imperative statement, and ensure contemporary, relevant and interesting contexts are incorporated into the Science classroom.

The importance of teaching science in relation to social contexts and issues is widely recognised (Holbrook, 2010; Kolstø, 2001; Millar, 2006; Pouliot, et al., 2010; Rennie, et al., 2007; Tomas, et al., 2011; Yore, et al., 2004). It is recommended that students be provided with a Science curriculum that allows them to question how science is being created and portrayed in society, and that they should be encouraged not to be overwhelmed by the scientific content they are presented with, as they may falsely believe they cannot engage with the science issues of today because they lack science knowledge (Kolstø, 2001). Students should be introduced to the issues in society that science provokes, with the hope that through this cultural and contextual relevance, they may understand enough and care enough about science that they take an interest in it as adults (DeBoer, 2000). Therefore, to promote the introduction of socio-scientific issues in Science, teachers should feel free to organise their Science teaching in a way that encompasses the science contexts that are relevant to their students.

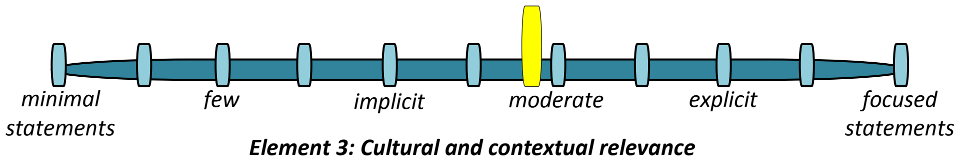
The *Australian Curriculum: Science* shows evidence of attempting to provide teachers with the freedom to explore science contexts of their choice with the inclusion of a variety of statements, namely: the curriculum does not *"prescribe approaches to teaching"* (Australian Curriculum, 2011, p. 7); the Content Elaborations throughout the year levels are provided to *"illustrate and exemplify content and assist teachers";* and that *"they* [the Content Elaborations] *are not intended to be comprehensive"* (Australian Curriculum, 2011, p. 7). Such statements can give the reader the feeling of choice and freedom when approaching the document, and can also indicate an intention by the curriculum to provide a backbone of content, without prescribing teaching techniques or contexts for students. There is also evidence of choice given in regards to the types of science investigations that are possible, with the use of clauses such as '*investigations can include…*', or '*this* [collection of data] *can involve*…' (Australian Curriculum, 2011). However, a strong indication that teachers have freedom to choose the contexts in which they believe their students will engage the most with the scientific content is through the use of the clause *"the choice of the approach taken will depend on the context…"* (Australian Curriculum, 2011, p. 5). This statement is attempting to provide the reader with the freedom to decide the cultural and contextual relevance that best suits their students, and is doing so in an unambiguous way.

Even so, due to the nature of a curriculum document, and its traditional meso structure as the deliverer of knowledge (as examined in Section 4.2.1 above), it could be predicted that teachers may not see these statements as a freedom to make choices, because they may interpret the text through their own beliefs, values and preconceived ideas (Chouliaraki & Fairclough, 1999). The structure and purpose of this curriculum document is seen as to provide information about what should happen in all Science classrooms in Australia. Therefore, even though teachers may read these statements and recognise the freedom being provided, they may inherently presume that they are the enactors of the document, and so should do everything exactly as it is stated.

Yet, there may still be an indication that teachers should choose the most appropriate contexts in which to teach their students, and this is provided by the opening paragraph of each year level Content Description. The start of each year level clearly states *"the order and detail in which the content descriptions are organised into teacher/learning programs are decisions to be made by the teacher."*

(Australian Curriculum, 2011, p. 18). From here, the Content Descriptions are open-ended and allow for flexibility in the teaching approach taken. The Content Elaborations are written to assist teachers with the planning, but can be overlooked by the reader if they so choose (ACARA, 2012a). However, it is anticipated that teachers will bring their own opinions and preconceived ideas to the document (Chouliaraki & Fairclough, 1999), and so will probably teach every one of the elaborations listed, whether they relate to the culture and context of their students or not. This is because teachers are often positioned by education policy and curriculum documents as requiring guidance and support, necessitating direct instruction on what to do (Ryan & Bourke, 2012; Thomas, 2005). Therefore, to provide licence for teachers to make choices about the contexts that are most appropriate for their students, the curriculum should be more general in its statements, and less descriptive in its elaborations.

Therefore, it can be concluded that even though the curriculum does promote students being exposed to the cultural and contextual relevance of science, by providing teachers with some freedom to investigate any social issues that are paramount to their students and their community (DeBoer, 2000; Holbrook & Rannikmae, 2007), the reality of teachers recognising and then embracing this freedom by choosing contexts that are most appropriate to their students, is somewhat limited. It is through the teachers' potential misinterpretation of the document's requirements, and their position of enactors of it, that may inhibit this key element for developing scientific literacy. In addition though, the document could be more specific in its instructions to teachers about choosing appropriate contexts, and it could actually provide less guidance in its Content Elaborations. Therefore, this key element for developing scientific literacy is rated on the continuum below.



Element 3: Cultural and contextual relevance

From the Melbourne Declaration, this key element has stayed the same. The document is seen to be encouraging the use of cultural and contextual relevance through the use of terminology and by structuring the content descriptions in a way that is open-ended. Therefore, the continuum indicator is relatively high. However, more could be done by the document to clarify to teachers their role in making the most appropriate choices for their students, and because of this, the continuum for this key element for developing scientific literacy is not any higher. Unfortunately, this means that the social problem of ambiguity within curriculum documents in regards to scientific literacy remains the same.

4.2.5 Micro Analysis – Element 4: Critical reflective practice

In this key element, students can develop critical reflective practices, examining how the science knowledge presented influences their own beliefs and pre-conceived ideas, and if the information presented has strong-enough evidence to challenge those ideas (Norris & Phillips, 2003), in an effort to develop as reflective citizens. Historically, Science curriculum documents have focussed on the delivery of scientific content (Bybee, 2009; Rennie, et al., 2007), and therefore critical reflective practices have rarely been included. This may lead to the conclusion that students traditionally see teachers as the deliverers of factual knowledge, above contestation and not open to debate. Further, at the macro level, scientific knowledge is privileged in our society as an evidence-based way of knowing (Ninnes, 2001). With this historical position in mind, it could be concluded that a curriculum document instructing teachers to promote critical reflective practices in their students, to determine the extent to which students' own ideals and beliefs influence how they comprehend the content, and potentially allow students to challenge their position on content areas, could be seen as a radical departure from normative scientific discourse.

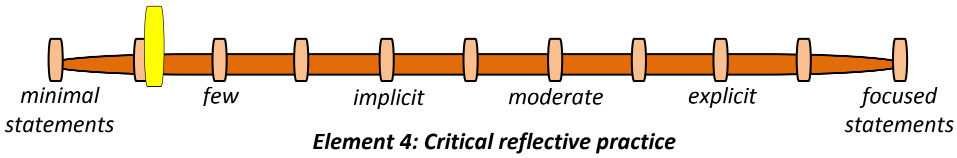
The *Australian Curriculum: Science* appears to challenge the marginalisation of limited critical reflective practice within Science classrooms with the inclusion of reflection in a more subtle and historically acceptable manner in the sciences. This is through the use of reflective practices in the Science Inquiry Skills strand. Included are descriptions such as *"Reflect on the investigation, including whether a test was fair or not"*, *"reflecting on investigations, identifying what went well, what was difficult…, and how well the investigation helped answer the question"*, *"reflecting on familiar situations…"*, *"applying experience from previous investigations…"*and *"Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected…"* (Australian Curriculum, 2011, pp. 33-49). The term 'reflect' (or reflection/reflecting) is used multiple times throughout the document, and always in regards to reflective practices (or technical checking) during investigations. There is limited evidence of the expectations of critical reflection (Mezirow, 2006) on one's own knowledge, influence, beliefs and actions about science and the particular use of scientific knowledge and procedures.

Unfortunately, such use of the term 'reflection' falls short of the key element of critical reflective practice as proposed by this investigation. There should be the inclusion of reflection by students on the beliefs they hold about science, its relationship to society, and the critical socio-scientific issues they may have to face. Students should understand that they come to Science with pre-conceived ideas about certain topics, and that these influence how they learn the information presented. There could be more recognition, by both the teacher and student, that how a reader (in this case, the student) positions themselves in relation to the text they are reading influences their ability to understand its technical, scientific language (Norris & Phillips, 2003). Traditionally, students may allow both the text and the presenting teacher to overshadow their background knowledge and beliefs, and accept whatever the text and teacher is saying (Norris & Phillips, 2003). The nature of science texts usually presented to students in school classrooms can make the assumption that the teacher, curriculum developer and textbook writer are ‘right’, and not to be challenged. There is a balance of agency that generally ensures the teacher and text are dominant, with the students being subservient (Kalantzis & Cope, 2008).

In contrast, this investigation suggests that students be taught how to analyse critically the scientific information with which they are presented, and reflect on their learning, to make informed and socially appropriate decisions about how the scientific information will influence their lives and the lives of others (Norris & Phillips, 2003). Students can be taught how to differentiate between statements in the text that assume, infer, hypothesise, conclude, justify an action, express a doubt or provide evidence for a claim (Norris & Phillips, 2003). If they fail to understand the difference between these types of scientific statements, then the text (and possibly even the teacher) may overwhelm them, and they may not fully comprehended the technical text they are reading, and may miss the scientific content altogether (Dijk, 2011; Norris & Phillips, 2003). Consequently, there should be a shift in the balance of agency between the teacher, text and student, so that learners can embrace critical reflective practice, and develop as reflective citizens, makers of their own knowledge, not just be receivers of it (Kalantzis & Cope, 2008).

It terms of the social problem under investigation in this study, it is discouraging that this document seems to use only a limited form of reflection in the Science

Inquiry Skills strand, and that this reductive use could actually inhibit the development of this aspect of scientific literacy in students. This may unfortunately maintain the current social problem of ambiguity within curriculum documents about the nature of scientific literacy. If the term 'reflection' is only ever used in conjunction with science investigations, teachers and students may misinterpret what they believe to be 'reflecting' in Science, and miss the purpose of critical reflection (Mezirow, 2006; Ryan, 2011) in and about the science they are learning. On this conclusion, the indicator on continuum for this key element for developing scientific literacy is moved slightly forward from where it was positioned after the Melbourne Declaration, and this is due to the inclusion of the term 'reflection' in the document. However, its position on the continuum, as seen below, cannot go any further until the more holistic meaning of critical reflection in Science (as explained above) is explicitly incorporated into the *Australian Curriculum: Science*.



Element 4: Critical reflective practice

More work could be done by the curriculum writers to recognise both the nature of critical reflection in science, and provide a clear explanation of why this critical reflective practice is so important to the development of scientific literacy in Australian students.

In summary, this *Australian Curriculum: Science* does not seem to overcome fully the social problem of ambiguity within curriculum documents on the nature of scientific literacy. The analysis presented above shows evidence of where the document does not provide a clear definition of what scientific literacy is or why it is important in Australian Science classrooms. For each key element for developing scientific literacy, Figure 6 below displays how the linguistic positions on the continua have changed from the Hobart Declaration through to the *Australian Curriculum: Science*.

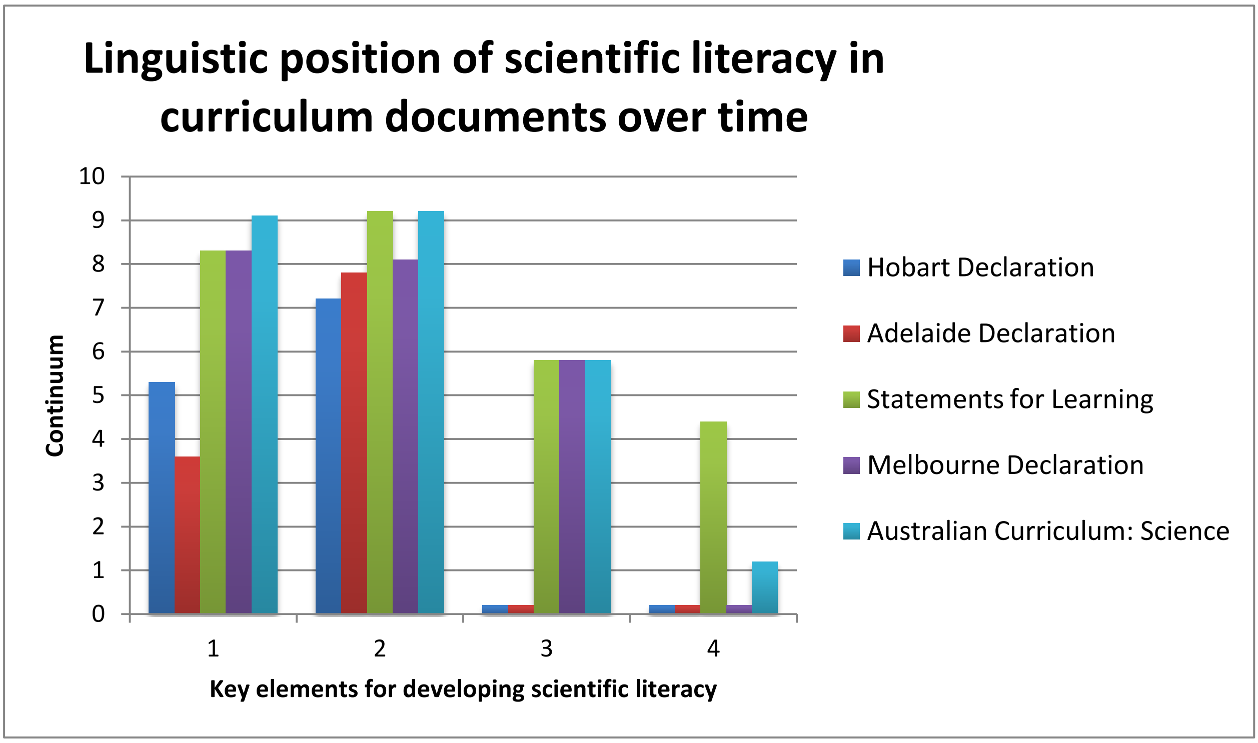


Figure 6: Linguistic position of scientific literacy over time

Although the evidence has shown progress made from the Melbourne Declaration, more can be done to ensure Science teachers have a clear understanding of scientific literacy and its key elements for development. This investigation will now continue by examining who may and/or may not benefit if this social problem of ambiguity within curriculum documents changes. From there, ways past the problem will be discussed, to provide recommendations to teachers about how to potentially overcome the ambiguity within the document and incorporate the four key elements for developing scientific literacy into their Science classrooms.

4.3 Who may and/or may not benefit if the social problem changes?

In this section, Step 3 of the critical discourse analysis process will be discussed. This will involve a discussion about Science students, one of the key stakeholders involved in the *Australian Curriculum: Science* document, to determine if they may and/or may not benefit from a change to the social problem, of ambiguity in curriculum documents surrounding the nature of scientific literacy.

As outlined in Chapter Two, there are a number of proposed definitions, alternative viewpoints and projected future directions for the term 'scientific literacy'. However, a common thread that runs through many of these various perspectives is that Science students, key stakeholders in the discussion of any Science curriculum, may benefit if focussed strategies for the development of scientific literacy are implemented in Science classrooms. Additionally, this investigation has proposed that the shift to the *Australian Curriculum: Science* has put Science teachers on the verge of a new chapter in science education, with an opportunity to re-examine their current curriculum and pedagogy, and determine if there are new opportunities to intentionally teach for scientific literacy. Therefore, this investigation suggests that a key stakeholder who may benefit from a change to the problem of ambiguity about scientific literacy, will be Science students.

Current research and literature has provided a variety of proposed strategies and benefits for students should the development of scientific literacy be less ambiguous, and become the focal point of Science classrooms. Examples of this include Holbrook's (2010) suggestion that the scientific literacy of students will advance in an *education through science* environment, where learning problem solving techniques, creativity, perseverance, ingenuity and how to work as a team will allow students to develop as responsible citizens who appreciate the significant role science plays in today's society. Yore, et al. (2003) suggest the focus for Science teachers could be on the explicit inclusion of language in science, and that all students of Science use written, visual and oral language, including various information sources to understand and then persuade others about science. Therefore, a disciplinary literacy approach could be taken, where Science teachers are focussed on the intentional teaching of literacy within Science (Freebody, et al., 2008; Moje, 2008). Such explicit teaching for disciplinary literacy and for scientific literacy could provide students with the strategies they may need to engage with the socio-scientific issues they may face in the future. This investigation suggests that this would benefit Science students, as the use of strategies such as these could bring the development of scientific literacy to the forefront of Science classrooms. This could then lead to the social problem changing, with scientific literacy becoming less ambiguous than what has been historically found in curriculum documents.

Additional examples of strategies that could also be utilised by Science teachers to promote the development of scientific literacy, and therefore allow students to benefit from a change to social problem, could also focus on comprehension strategies in Science. This may include students being taught how to differentiate between statements in the text that assume, infer, hypothesise, conclude, justify an action, express a doubt or provide evidence for a claim (Norris & Phillips, 2003). This could demonstrate not only intentional teaching for scientific literacy, but also improve achievement in the science classroom, because if students fail to understand the difference between these types of scientific statements, they may not have fully comprehended the technical text they are reading, and therefore may have missed the scientific content altogether (Dijk, 2011; Norris & Phillips, 2003).

Overall, this investigation proposes that a change to the social problem, that is ambiguity in Science curriculum documents about nature of scientific literacy, is likely to benefit Science students. Although the results of the micro analysis presented in section 4.2 above suggests that there is still ambiguity in the *Australian Curriculum: Science* document, Science teachers may still be able to overcome this ambiguity if they choose to re-evaluate their Science teaching to determine if scientific literacy is a focal point. There can be an opportunity for Science teachers to intentionally teach for scientific literacy under this new *Australian Curriculum: Science*, and rise above the ambiguity within the document, to ensure the Science students of Australia develop scientific literacy. This investigation will now continue by providing recommendations about how Australian Science teachers can teach the new *Australian Curriculum: Science* with a focus on scientific literacy.

4.4 Ways past the problem

Now that the key elements for developing scientific literacy proposed in Chapter 2 have been evaluated against the linguistic discoveries made in section 4.2, a set of recommendations for intentional teaching for scientific literacy can be made, so that teachers can be provided with practical advice about how to potentially improve the scientific literacy of their students.

To begin, the background of this research needs to be reiterated, where the explicit teaching of English language literacy in secondary schools has not traditionally been seen by some practitioners as part of a science teacher's role (Alvermann, et al., 2011; Hanrahan, 2009), and so some may not allocate time for literacy instruction in their classrooms (Fang & Wei, 2010). In addition to this, Science teachers could be hesitant to attempt the explicit teaching of scientific literacy (Yore & Treagust, 2006), and may find difficulties when attempting to incorporate literacy strategies, such as teaching text structure, approaches for reading aloud and concept mapping, into Science lessons (Fang & Wei, 2010). However, this investigation has provided research to show that the nature of science requires that students are able to comprehend a variety of language conventions, text types and modalities, and that without intentional teaching for scientific literacy and comprehension, there may be poor understanding of the content material (Fang & Wei, 2010; Zywica & Gomez, 2008). Therefore, this investigation strives to provide strategies for teachers to assist them in bridging the gap that has traditionally existed between Science education and literacy practices in Science classrooms (Fang & Wei, 2010) and will now outline how teachers could incorporate targeted scientific literacy activities into their Science classrooms.

Science courses could now address the fundamental sense of scientific literacy (where reading, writing and comprehension of multiple texts and contexts are paramount), and encourage students to be exposed to the interconnectedness of science and how it is constructed (Norris & Phillips, 2003). Fang & Wei (2010), along with Alvermann, et al. (2011) suggest that critical reading time should be incorporated into Science classrooms, whilst DeBoer (2000) describes the future of scientific literacy as one where students are introduced to the issues in society that science provokes, with the hope that they understand enough and care enough about science that they take an interest in it as adults. In addition to this, the future for scientific literacy supported by many in the literature is that the teaching of Science should concentrate on how it relates to social contexts and issues (Holbrook, 2010; Kolstø, 2001; Millar, 2006; Pouliot, et al., 2010; Rennie, et al., 2007; Tomas, et al., 2011; Yore, et al., 2004), with a strong focus on the moral and ethical viewpoints of the students (Tomas, et al., 2011).

From this research into the future of scientific literacy, the four key elements for developing scientific literacy proposed by this investigation were outlined in section

2.3, and used to evaluate the linguistic position of scientific literacy within the document throughout section 4.2. These elements will be used again to detail how teachers could approach intentional teaching for scientific literacy whilst implementing the *Australian Curriculum Science*.

4.4.1 Element 1: Scientific knowledge in its multiple representations

To grasp the nature of science and how it is both influenced by and in turn influences society, students should know enough scientific content and knowledge to distinguish science from non-science, so that they can critically analyse 'science' as it is presented in the media (DeBoer, 2000; Norris & Phillips, 2003).

There may never be clear agreement both between and within educational authorities and the scientific community about the extent and depth of the scientific content to be taught in schools. This could be due to the nature of science, with its ever-expanding fields of study, and the continual discoveries and advancements made through new technologies. However, this key element for developing scientific literacy is not determined by how many hours should be spent studying scientific theory in the classroom, or what topics/fields of science the lessons should contain. This key element is driven by the notion that Science students need *enough* scientific content to distinguish 'science' from 'non-science', when it is presented in a way that influences their world (for example, in the media). How much scientific content is *enough* for Australian students is difficult to determine, as the ever-changing society that these students will encounter throughout their lifetime controls the extent of scientific content required.

Consequently, teachers should not be concerned with trying to determine if the *Australian Curriculum: Science* provides their students with *enough* scientific content and knowledge, or potentially debating whether more or less content should have been included or excluded. To promote the development of scientific literacy, teachers can focus on a student-centred learning environment (Goodrum, et al., 2000), determining how to focus their teaching and curriculum planning around the current needs of their students. The Content Descriptors outlined by the *Australian Curriculum: Science* are seen to be broad enough to allow teachers and curriculum planners to focus on the important knowledge for their students at the convergence of a particular point in space and time. In fact, with such broad sweeping content knowledge statements, teachers could adapt their teaching content to move with current socio-scientific issues.

There are many ways in which this movement, away from scientific content and knowledge, towards current socio-scientific issues and scientific literacy, could be made. To begin, the current graphical representation by the *Australian Curriculum: Science* document of the how the three strands of Science Understanding, Science as a Human Endeavour and Science Inquiry Skills are interwoven could be improved. Figure Seven shows the current representation, as presented in the *Australian Curriculum: Science*, and this graphic could potentially be misinterpreted by teachers as valuing Science Understanding 'above' and 'overarching' Science as a Human Endeavour and Science Inquiry Skills, by both its position in the graphic and the size and space given to this strand. This graphic could maintain the current belief that scientific content and knowledge is the most important aspect of Science learning (Goodrum, et al., 2000), as seen below:

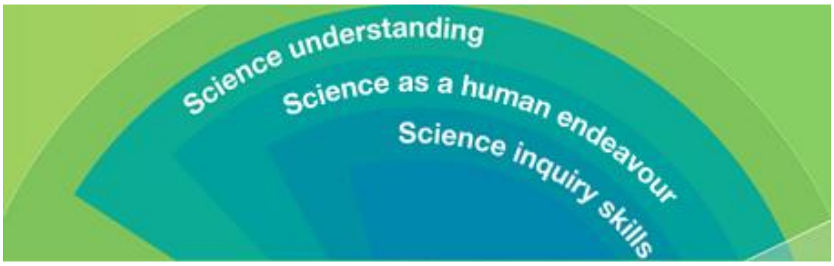


Figure 7: Graphic representation of the three stands of science learning, as presented by the Australian Curriculum: Science (ACARA, 2012f)

In comparison, the New South Wales Department of Education and Communities displays what could be a more accurate representation of the relationship between these three stands. This graphic displays how each strand contributes equally to science learning, as seen in Figure Eight below:

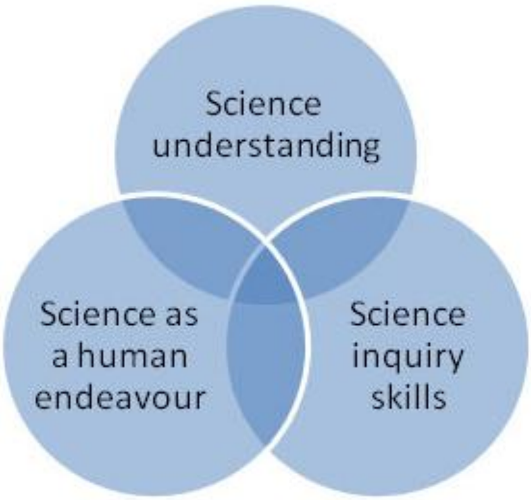


Figure 8: Graphic representation of the three stands of science learning, as presented by the New South Wales Department of Education and Communities (State of New South Wales through the Department of Education and Communities, 1999 - 2011)

However, this investigation proposes the modification of Figure Ten to introduce teaching for scientific literacy as the central factor of all three science learning strands. Such promotion of the central nature of scientific literacy to Science learning may assist teachers in understanding its place in their Science teaching. In addition, this graphic representation will hopefully clarify for teachers the equal contributions that each of the three strands presented by the *Australian Curriculum: Science* make to science learning, as presented in Figure Nine below:

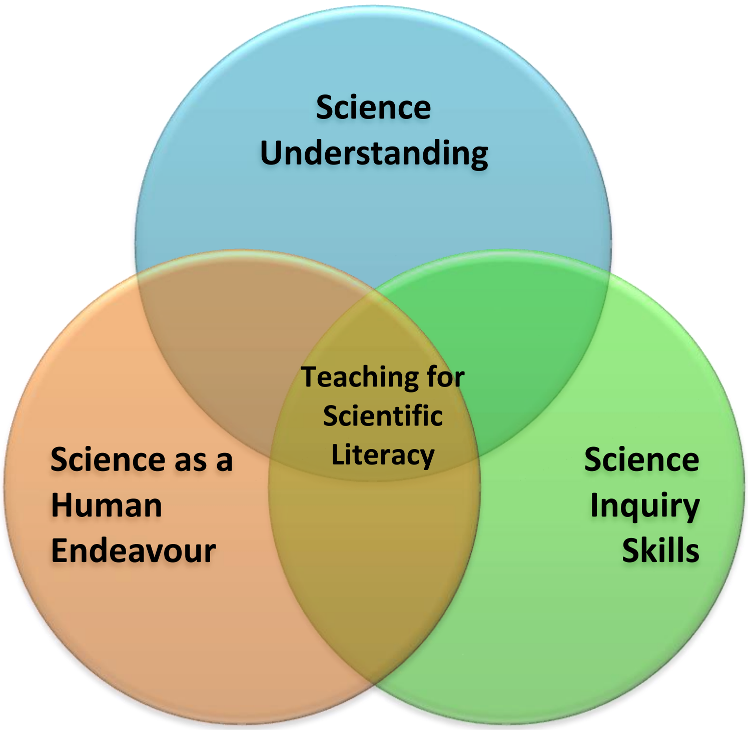


Figure 9: Graphic representation of the three stands of science learning, as proposed by this investigation

In addition to using this graphic representation to demonstrate the central nature of teaching scientific literacy, school curriculum planners and teachers are recommended to view the *Australian Curriculum: Science* with limited weight given to the Content Elaborations. As stated, readers of a text will internalise other discourse moments (Chouliaraki & Fairclough, 1999), and so teachers can traditionally assume all content information provided by a curriculum document is mandatory. However, if the curriculum is viewed with limited weight given to the Content Elaborations initially, teachers can be impelled to investigate how each Content Description relates directly to their students in the current social climate, they may come to see current events and socio-scientific issues that relate in their school context. This curriculum planning technique, of evaluating the content knowledge described against the current interests and societal context of the student, has also been recommended by the literature to help develop scientific literacy (Goodrum, et al., 2000).

A demonstration of how this technique of evaluating of the Content Descriptor against the current societal context of the students is now provided. In the Year Nine curriculum, the Content Description *"Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems* (Australian Curriculum, 2011, p. 58)*"* is quite broad and could cover a number of contexts. For example, in schools situated in urban environments, the Content Descriptor could be investigated through analysis of the impacts of housing developments on the local environment, and discuss the socio-scientific issues surrounding the construction of human-made ecosystems (for example, artificial canals and lakes). For schools with a focus on global perspectives in Science, this same Content Descriptor could be investigated through the context of global warming and climate change.

The three examples provided above demonstrate how Key Element One for developing scientific literacy could be taught through the *Australian Curriculum: Science*. In each case, students can learn the mandatory Content Descriptor outlined by the curriculum document, but would do so in a way that incorporates their context and interests. This can provide them with *enough* scientific content and knowledge about that scientific situation to understand what is happening around them, and should give them the opportunity to engage with the science presented to them by the society in which they live. Therefore, curriculum planners and teachers are recommended to approach the Content Descriptors of the *Australian Curriculum: Science* with the intent to evaluate each descriptor against the societal context of the students, to determine the amount of content that needs to be covered. This could ensure that teachers recognise the value of delivering scientific content to their students that is relevant and promotes scientific literacy. Therefore, this investigation recommends that curriculum planners and teachers view the Content Descriptions <u>with limited weight</u> given to the Content Elaborations, and that they should evaluate each Content Description against the societal context of their students, to determine that the amount of content to be covered is appropriate for their students. To assist with the implementation of this recommendation, professional development strategies for teachers can also be introduced, to support teachers in moving from a curriculum plan that may value a traditional content-driven focus, to learning experiences that can value the societal context of science and promote scientific literacy (Goodrum, et al., 2000), which is important to science learning.

4.4.2 Element 2: Social relevance

As stated previously, this investigation proposes that for students to become scientifically literate, they need scientific knowledge to participate intelligently in science-based social issues, adapt to a rapidly changing world, function as responsible and informed citizens and have societal usefulness (DeBoer, 2000; Dillon, 2009; Holbrook, 2010; Holbrook & Rannikmae, 2009; Norris & Phillips, 2003). Therefore, the science these students learn should be relevant to the socio-scientific issues they are likely to face (or that are relevant to their lives at this present time).

As shown in Section 4.2.3, evidence of the social relevance of science can be seen in the discourse of science learning throughout the document. The opening paragraphs and aims link the importance of learning science to our personal, social and economic lives, and this relationship between science and society can be concluded as being placed 'above' the learning of scientific content and knowledge in the curriculums aims. In addition, the Science as a Human Endeavour strand incorporates socio-scientific issues, and aims to ensure students develop as responsible and informed citizens. Furthermore, this proposed key element for developing scientific literacy links clearly with Key Element One: Scientific knowledge in its multiple representations, and so if the Content Descriptions in the *Australian Curriculum: Science* are evaluated against the societal context of the students (as is recommended), to determine the specific content students may need to ensure they can intelligently participate in the society around them, then students can also develop as informed students who have societal usefulness.

Therefore, this investigation recommends that for this key element for developing scientific literacy to be embraced, teachers should place a high value on the Science as a Human Endeavour Content Description statements provided in the document. For this to occur, Science teachers may need to relinquish their traditional valuing of scientific content and knowledge (Goodrum, et al., 2000). Moreover, future versions of the *Australian Curriculum: Science* document could demonstrate a high valuing scientific literacy and the Science as a Human Endeavour strand by providing this strand with equal space value in the document (Fairclough, 2003) to that of the Science Understanding strand.

In the school environment, this valuing of the Science as a Human Endeavour strand could occur through the following three ways. Firstly, as curriculum planners and teachers are being supported by professional development strategies to evaluate the Content Descriptors against the current societal climate of their students (as recommended for the development of Key Element One), they can also align the appropriate Science as a Human Endeavour Content Descriptors at the same time. The Science as a Human Endeavour Content Descriptors can be embedded into the curriculum plan. This is demonstrated in the graphic representation proposed by this investigation showing how the three strand of science learning contribute equally to teaching for scientific literacy. In practice, an example of this, using the same Science Understanding Content Descriptor as detailed in Key Element One above, *"Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems* (Australian Curriculum, 2011, p. 58)*"*, teachers could incorporate the Science as a Human Endeavour descriptor *"People can use scientific knowledge to evaluate whether they should accept claims, explanations of predictions* (Australian Curriculum, 2011, p. 61).*"* These two descriptors can be investigated in the context of wide-scale environmental change and global warming. Such incorporation of the Science as a Human Endeavour strand into the initial stages of planning for curriculum planners and teachers shows it receiving the same value as scientific content, and these actions could demonstrate to students the cultural and contextual relevance of the science they are learning (which also encourages the development of Key Element Three for developing scientific literacy).

Secondly, if the above example is used, teachers could also incorporate societal opinions and ideas into their teaching, by utilising media releases, news articles and other mass-media on the context of environmental change and global warming. These additional resources can be used to facilitate discussions about how the scientific content that is being taught relates to society around them, and what influence science knowledge and scientific developments are having on society. Incorporation of these non-traditional science text types can also encourage student exposure to multimodal texts (as desired by Key Element One), and encourage the explicit teaching of comprehension and composition strategies in the Science classroom (a suggested strategy for this is described in section 4.4.4 below).

Finally, this combination of Science as a Human Endeavour and Science Understanding Content Descriptors could be further valued by their incorporation into assessment items. Teachers have traditionally highly valued assessment to demonstrate what students have achieved (Goodrum, et al., 2000), and so a strategy that promotes the value of the Science as a Human Endeavour strand to both teachers and students could be to have items that include open-ended scenarios requiring students to relate their scientific content and knowledge to society. One way this could be achieved in the example cited above, is by providing students with an excerpt from a text (for example, news article or editorial piece) on global warming, and asking them to provide a scientific response that addresses the issue. If this type of scientific response to a socio-scientific issue is required on an assessment item, teachers would need to ensure their students have the content knowledge required to address scientifically the scenario (using *enough* scientific content to satisfy Key Element One), as well as guaranteeing their students understand how the science knowledge they have learnt relates to the particular socio-scientific issue, satisfying Key Element Two. Again, professional development strategies can be used to assist teachers with how to ensure their assessment items value Science as a Human Endeavour, promote scientific literacy as a learning outcome (Goodrum, et al., 2000).

Therefore, to assist in the progress of Key Element Two for developing scientific literacy, and cultivate students who are able to responsibly and intelligently participate in the world around them, teachers should be encouraged to value and incorporate the Science as a Human Endeavour strand into their teaching practice. Consequently, this investigation recommends that teachers be provided with guidance to plan the Science as a Human Endeavour Content Descriptors with the same importance as the Science Understanding Content Descriptors, and embed them into both their teaching and assessment practices.

4.4.3 Element 3: Cultural and contextual relevance

For scientific literacy to develop, students should understand the relevance of science to oneself, to culture and to their community (DeBoer, 2000; Holbrook & Rannikmae, 2007), and the curriculum can assist in this by giving teachers the freedom to investigate any social issues that are paramount to their students and community. As described in section 4.2.4 above, there was evidence within the document of teachers being given the freedom to investigate any social issues that are paramount to their students, with clauses such as *"the choice of the approach taken will depend on the context…"* (Australian Curriculum, 2011, p. 5) and *"the order and detail in which the content descriptions are organised into teacher/learning programs are decisions to be made by the teacher."* (Australian Curriculum, 2011, p. 18). These statements attempted to provide the reader with the freedom to decide the cultural and contextual relevance that best suits their students.

The importance of teaching science in relation to social contexts and issues is well documented (Holbrook, 2010; Kolstø, 2001; Millar, 2006; Pouliot, et al., 2010; Rennie, et al., 2007; Tomas, et al., 2011; Yore, et al., 2004). Students should be provided with a Science curriculum that allows them to be introduced to the issues in society that science provokes, and question how the science is being created and portrayed. It is anticipated that through this cultural and contextual relevance they may understand enough and care enough about science to take an interest in it as adults (DeBoer, 2000). Even so, due to the nature of a curriculum document, and its traditional meso structure as the deliverer of knowledge, teachers may not necessarily see this clause as the freedom to make choices for their students, rather they may be more likely to interpret the text through their own beliefs, values and preconceived ideas (Chouliaraki & Fairclough, 1999). Therefore, even though the Content Descriptors are the only mandatory component of the curriculum, with the Content Elaborations provided only as suggestions (ACARA, 2012b; Australian Curriculum, 2011), teachers as enactors of the document may presume that they are to teach every one of the elaborations listed, whether they directly relate to the culture and context of their students or not.

Therefore, to provide students with a Science curriculum with cultural and contextual relevance, this investigation recommends that the curriculum be read by curriculum planners and teachers with limited weight given to the Content Elaborations, and that professional development be used to assist with this. This recommendation links clearly with Key Element One and the recommendation that teachers can analyse the Content Descriptors in light of the social context of their students, to ensure the scientific content and knowledge taught is *enough* for their students to be able to participate in the world around them, thus developing scientific literacy (Goodrum, et al., 2000). In addition, this recommendation also aligns with Key Element Two, where students should recognise the social relevance of the science they are learning, and therefore have clear links between the societal context of the Content Descriptors and the Science as a Human Endeavour strand.

4.4.4 Element 4: Critical reflective practice

For this key element for developing scientific literacy, students should reflect on their practice and how beliefs and pre-conceived ideas can influence the science learning that occurs in the classroom (Norris & Phillips, 2003), in an effort to develop as reflective citizens. In the *Australian Curriculum: Science*, there was partial evidence of reflection discovered, and it was limited to the Science Inquiry

Skills strand. This regrettably falls short of the reflective practice proposed by this investigation, where critical reflection (Mezirow, 2006) on one's own knowledge, influence, beliefs and actions about science and the particular use of scientific knowledge and procedures is desired.

There should be recognition, by both the teacher and student, that how a reader (in this case, the student) positions themselves in relation to the text they are reading can influence their ability to understand its technical, scientific language (Norris & Phillips, 2003), and that the nature of science texts usually presented to students in school classrooms can give agency to the teacher and text (Kalantzis & Cope, 2008), assuming both are 'right', and not to be challenged. In contrast, this investigation recommends that students be taught how to analyse critically scientific information, reflect on their learning, and make informed and socially appropriate decisions about how the scientific information they are presented with influences their lives and the lives of others (Norris & Phillips, 2003).

To achieve this, it is recommended that students be taught how to differentiate between statements in the text that assume, infer, hypothesise, conclude, justify an action, express a doubt or provide evidence for a claim (Norris & Phillips, 2003), and to understand their own positioning in relation to the text. For this to occur, teachers should recognise the value of critical reflection and intentionally teach reflection strategies to their students. An examples of this, continuing to use the Year Nine Content Descriptors, *"Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems* (Australian Curriculum, 2011, p. 58)*"* and *"People can use scientific knowledge to evaluate whether they should accept claims, explanations of predictions* (Australian Curriculum, 2011, p. 61)*"*, could be for teachers to utilise news articles and the science presented in the media about global warming and climate change (as recommended for Key Element Two), and employ scaffolded comprehension strategies, where students are prompted to investigate their own opinions about global warming and climate change both prior to and after the teaching of the scientific content.

One type of comprehension strategy that could be utilised is Reciprocal Teaching, a instructional procedure developed by Palincsar and Brown (Spörer, Brunstein, & Kieschke, 2009) that can improve students' comprehension skills though a scaffolded, four step approach of Question, Summarise, Clarify, and Predict (Spörer, et al., 2009; Stricklin, 2011). This explicit teaching strategy can promote student engagement with the text to improve their comprehension skills, and provides a scaffolded approach to literacy instruction that can be used with science texts (Spörer, et al., 2009). Use of a scaffolded strategy such as this, by Science teachers could encourage the incorporation of reading, comprehension, composition and literacy instruction time into the Science classroom.

It is anticipated that as teachers and students become more familiar with critical reflective practice, it may become more common-place in Science classrooms around Australia. As detailed in section 4.4.2, the Science as a Human Endeavour Content Descriptors can encourage teachers to link scientific content and knowledge with social relevance, and ensure students are exposed to socio-scientific issues. Whilst teachers are incorporating these Content Descriptors into their teaching practice, thus exposing students to socio-scientific issues, and additionally utilising explicit teaching methods and comprehension strategies, it is anticipated that the nature of Science learning may become a reflective form of learning. For example, when students are expanding their curiosity, asking questions and showing a willingness to explore how science changes the world in which they live, as desired by the 'first' aim of the *Australian Curriculum: Science*

(Australian Curriculum, 2011), students can be encouraged to question critically their own beliefs and ideas.

Therefore, this investigation recommends the incorporation of critical reflective practices throughout Science learning in the classroom. This is to be achieved by exposing students to multi-modal texts that present socio-scientific issues in society, and the use of scaffolded comprehension strategies, to encourage students to analyse critically the science that is presented to them and how it interacts with their own pre-conceived beliefs and ideas about scientific knowledge. This focus on critical reflection and socio-scientific issues can ensure scientific literacy is central to Science learning, and that each of the three strands science learning presented in the *Australian Curriculum: Science* are valued in Science classrooms.

In summary, this investigation has made recommendations for each of the key elements for developing scientific literacy, to provide ways past the social problem of ambiguity within curriculum documents about the development of scientific literacy. Each of these recommendations is underpinned by a desire for professional development strategies that can assist teachers in recognising both the importance of scientific literacy and the importance of intentionally teaching for scientific literacy. These professional development strategies should focus on teaching for scientific literacy as central to Science learning, as presented by Figure Nine, and how each of the three strands of science learning in the *Australian Curriculum: Science* can contribute equally to teaching for scientific literacy. Table 2 below represents how these recommendations are linked to each of the key elements for developing scientific literacy.

Table 2: Recommendations for embracing the key elements for developing scientific literacy

Recommendation	**Key elements for developing scientific literacy**			
	1: Scientific knowledge in its multiple representations	**2: Social relevance**	**3: Cultural and contextual relevance**	**4: Critical reflective practice**
Use of the graphic representation of scientific literacy (developed by this investigation)	Promotes scientific literacy across all strands of the Australian Curriculum: Science			
Science Understanding Content Descriptors (adapted from existing literature and developed by this investigation)	Read without Content Elaborations		Read without Content Elaborations	
Science Understanding Content Descriptors (adapted from existing literature and developed by this investigation)	Evaluate against student social context	Evaluate against student social context	Evaluate against student social context	
Science as a Human Endeavour Content Descriptors (developed by this investigation)		Align with Science Understanding Content Descriptors		Align with Science Understanding Content Descriptors
Multimodal texts (adapted from existing literature and developed by this investigation)		Incorporate into teaching practice		Incorporate into teaching practice
Multimodal texts (adapted from existing literature and developed by this investigation)		Incorporate into assessment items		
Scaffolded comprehension (adapted from existing literature)				Use of strategies like Reciprocal Teaching
Critical reflection (adapted from existing literature)				Utilise before and after topic

4.5 Critical reflections on the analysis process

Critical discourse analysis should contain a reflection by the analyst on the position from which they carried it out (Chouliaraki & Fairclough, 1999). This section contains my reflection, written in first person, to explain my position in conducting the critical discourse analysis of the *Australian Curriculum: Science* document.

The critical discourse analysis of the *Australian Curriculum: Science* began with an investigation of the curriculum documents that came before it. This included the Hobart, Adelaide and Melbourne Declarations, as well as the *Statement of Learning for Science*. It is evident from the macro analysis completed in Section 4.1 that the investigation into these curriculum documents was solely an overview of their development, and did not contain any contact with the developers, writers or implementers of the document. There could be no assistance provided by the writers of the document to explain how they developed the goals for national schooling in Australia, or what their perspectives were on scientific literacy and its place in the curriculum. The decisions I made on how scientific literacy was linguistically positioned in the document, and the subsequent ratings I gave the documents on the continuums representing the key elements for developing scientific literacy, came from my interpretation of the goals and statements within the document. I recognise this as a limitation of the analysis, and that a greater understanding of the declaration documents could have been obtained if contact with the writers had been possible.

The same limitation also applies to the analysis of the *Australian Curriculum: Science* document. My inability to have direct contact with the curriculum developers/writers meant that the analysis was based on my interpretation of how scientific literacy was linguistically positioned, using only the text in the document itself, and not the writers' perspectives. Therefore, a greater understanding of why certain statements were made, and how scientific literacy was meant to be portrayed in the document would have been gained through interaction with the curriculum developers.

However, even with these limitations, I believe my interpretations and perspectives on how scientific literacy is linguistically positioned within these declarations and the *Australian Curriculum: Science* are valid. As an Australian Science teacher, one of my tasks is to read and interpret curriculum documents, exclusive of contact with the writers and developers. I believe I represent the typical Science teacher in Australia, coming to this document with preconceived ideas and beliefs on what the curriculum should contain, and influenced by my previous experience with curriculum documents and how they have evolved throughout my teaching career. The purpose of my research was to emulate how the typical Australian Science teacher could read and interpret the document, and whether or not they could gain an understanding of scientific literacy from its text alone. Therefore, focusing on the text, and not including the perspectives of the curriculum writers (which a typical Australian Science teacher may not have access to) can produce legitimate results for this research.

On a more personal note, this research investigation has challenged the preconceived ideas I had about scientific literacy as a practicing Science teacher. As stated in the vignette at the start of this thesis, I was surprised when students in my Science classes were so accepting of the scientific content and knowledge being presented to them, and that they were not confident in completing critical analysis of scientific data. However, after reviewing the literature on scientific literacy and completing a critical discourse analysis of the *Australian Curriculum: Science*, I recognise now that efforts must be made by curriculum writers and teachers to ensure students develop scientific literacy. I now clearly see the value of scientific literacy, and that efforts to develop it must be targeted and intentional. I hope that my conclusions from this research investigation will help other Science teachers to also see the value in scientific literacy, and come to an understanding of what it is and how they can intentionally teach for it in their classrooms.

4.6 Summary

Chapter Four began by identifying that the social problem determined by this investigation is the there has historically been a gap between the intentions of Science Curricula and what actually happens in the classroom (Hackling, et al., 2001), and that this is compounded by the ambiguity traditionally found in Science curriculum documents about what scientific literacy is and its importance to Australian students. Section 4.1 introduced the "Continua of Scientific Literacy" (as developed by this investigation) to determine the position of the four proposed key elements for developing scientific literacy in each of the curriculum documents investigated. Throughout Subsections 4.1.1 through to 4.1.3, the Hobart, Adelaide and Melbourne Declarations, along with the *Statements for Learning,* were analysed, to discover the context in which the *Australian Curriculum: Science* is situated, and that this new curriculum starts from a position that contains some ambiguity towards scientific literacy.

The use of critical discourse analysis techniques to determine the linguistic position of scientific literacy in the *Australian Curriculum: Science* was detailed in Section 4.2. Subsection 4.2.1 investigated the meso level of the document, with Subsections 4.2.2 through 4.4.5 analysing the document against each of the four key elements for developing scientific literacy proposed by this investigation. Through the use of knowledge exchange statements, underpinned by activity exchange assumptions (Fairclough, 2003), this investigation concluded that there is still ambiguity within the *Australian Curriculum: Science* on a number of the key elements for developing scientific literacy. Key Elements One and Two showed promising results, seeming to move towards having focused statements about scientific literacy in the document. Key Element Three seemed to show some improvement from previous policy and curriculum documents, but could still only be rated as having implicit to moderate statements about scientific literacy. Key Element Four can be concluded as still quite ambiguous in this new curriculum, with only a few statements about reflection and its importance to scientific literacy discovered.

Section 4.3 continued the critical discourse analysis by briefly detailing how Science students could be one of the key stakeholders in the *Australian Curriculum: Science* that may benefit if the social problem, of ambiguity in curriculum documents about the nature of scientific literacy, were to change. This section was then followed by 4.4, where suggested ways past the social problem of ambiguity within curriculum documents were provided. These recommendations, detailed for each key element for developing scientific literacy, included the proposal of a new graphic representation to show the central nature of teaching for scientific literacy. For Key Elements One and Three, curriculum planners and teachers were recommended to examine the Science Understanding Content Descriptors, with limited weight given to the Content Elaborations, and to evaluate each Content Descriptor against the social context of their students. It was recommended for Key Element Two that the Science as a Human Endeavour Content Descriptors were aligned with the Science Understanding Content Descriptors, and that multimodal texts were incorporated into Science teaching practice and assessment items. Finally, to encourage critical reflection for Key Element Four, teachers should utilise multimodal texts, comprehension strategies and the Science as a Human Endeavour Content Descriptors to explore different viewpoints about socio-scientific issues. Further, discussions about pre-conceived ideas and beliefs about science should be utilised throughout the teaching of all science topics.

Section 4.5 was the final part of Chapter 4, providing a reflection by the analyst on the critical discourse analysis process. This section outlines the position from which the analysis was undertaken, and how even though there were some limitations of the analysis acknowledged, the results and conclusions of this investigation are valid. Chapter Five will now summarise this investigation, reflecting on the aim and research questions proposed, and the outcomes and recommendations presented by the linguistic analysis of the document.

Chapter 5: CONCLUSIONS

In this final Chapter, this investigation will be summarised, with recommendations and future research possibilities explored. Section 5.1 will review the purpose of the investigation, determining if the research aim has been achieved, and if the research questions were answered. This will be followed by Section 5.2, which will summarise the findings of the critical discourse analysis of the *Australian Curriculum: Science* document. Section 5.3 will outline recommendations developed from the results of this analysis, both for policy and curriculum developers, as well as teachers who are implementing the *Australian Curriculum: Science*. The limitations of the findings will be explored in Section 5.4, followed by Section 5.5, which will explain the significance of this investigation and the future research possibilities. This Chapter finishes with closing remarks and conclusions in Section 5.6

5.1 Review of research aim

The teaching of English language literacy in secondary schools is traditionally not seen as part of a Science teacher's role (Alvermann, et al., 2011; Hanrahan, 2009), and so teachers may not allocate time for literacy instruction in their classrooms (Fang & Wei, 2010). Science teachers could be hesitant to attempt the intentional teaching of scientific literacy (Yore & Treagust, 2006), and may find difficulties when attempting to incorporate literacy strategies, such as teaching text structure, approaches for reading aloud and concept mapping, into Science lessons (Fang & Wei, 2010). Therefore, this investigation has strived to provide strategies for teachers to assist them in bridging the gap that has traditionally existed between Science education and literacy practices in Science classrooms (Fang & Wei, 2010), endeavouring to show that the nature of science requires that students are able to comprehend a variety of language conventions, text types and modalities, and that without intentional teaching for scientific literacy and comprehension, there may be poor understanding of the scientific content material (Fang & Wei, 2010; Zywica & Gomez, 2008).

The aim of this investigation, as outlined in Section 1.3, was:

> *To determine, using critical discourse analysis, what meaning and value has been placed on scientific literacy in the new Australian Curriculum: Science, and how Science teachers are expected to respond to this placement of scientific literacy in regards to their intentional teaching for it.*

This research aim has been achieved, with a critical discourse analysis based on the work of Fairclough (2003) revealing that scientific literacy is somewhat ambiguous within the *Australian Curriculum: Science* document. This investigation made visible the findings that some aspects of scientific literacy, namely Key Elements One and Two as proposed by this investigation, which deal with the scientific content and knowledge required to understand science, and how the social relevance of science should be incorporated into Science teaching, were more prominent in the curriculum document. However, Key Elements Three and Four, addressing the teaching of science in cultural and contextual relevance, and critical reflection practices to develop students as reflective citizens, were implicit within the document.

The research questions that stemmed from the aim of this investigation were:

1. What does the current literature say about scientific literacy and its importance for Science educators?
2. How does the new *Australian Curriculum: Science* represent scientific literacy as both concept and pedagogy?

3. How can Science educators combine the new *Australian Curriculum: Science* and intentional teaching for scientific literacy in a successful manner?

The three research questions have been addressed throughout this thesis. Question One is explored in Chapter 2 of this study. Current literature revealed that there is no clear definition of the term 'scientific literacy' (DeBoer, 2000), but that many alternative viewpoints are prevalent (DeBoer, 2000; Dillon, 2009; Freebody, et al., 2008; Holbrook, 2010; Holbrook & Rannikmae, 2009; Moje, 2008; Murcia, 2009; Yore & Treagust, 2006). However, even with this uncertainty in the definition, the importance of Science educators intentionally teaching for scientific literacy is strongly recommended (Rennie, et al., 2007), with the suggestion that Science teachers concentrate on the discourses used to present socio-scientific issues (Holbrook, 2010; Kolstø, 2001; Millar, 2006; Pouliot, et al., 2010; Rennie, et al., 2007; Tomas, et al., 2011; Yore, et al., 2004). From this literature review, the four key elements for developing scientific literacy were proposed: (1) Scientific knowledge in its multiple representations; (2) Social relevance; (3) Cultural and contextual relevance; and (4) Critical reflective practice. These elements were developed, not only to assist with the critical discourse analysis of the *Australian Curriculum: Science*, but also to help teachers to understand some of the different facets of scientific literacy. With there still no clear definition of scientific literacy, it is hoped that these identified 'key elements' of scientific literacy will help teachers to better grasp what is meant by the term, and how to intentionally teacher for it.

Research Question Two asked how scientific literacy was linguistically positioned in the new *Australian Curriculum: Science*, and this position was exposed in Chapter 4. The social problem of ambiguity within Australian policy and curriculum documents, in relation to scientific literacy and how it can be incorporated into Australian Science classrooms, was maintained in this document. Two of the four key elements for developing scientific literacy proposed by this investigation were implicit in the document, and therefore Science teachers may not readily grasp the nature of scientific literacy through this document.

The final research question, asking how Science teachers can to combine intentional teaching for scientific literacy with the new *Australian Curriculum: Science* was explored in Chapter 4.4. Recommendations were made as to how Science teachers intentionally teach for scientific literacy using the *Australian Curriculum: Science*. These recommendations include: guidance for dealing with the Science Understanding and Science as a Human Endeavour Content Descriptors; the introduction of multimodal texts; the incorporation of social, cultural and contextual relevance; and the use of critical reflection practices into their Science teaching.

5.2 Summary of findings

This research endeavoured to find an awareness of how the *Australian Curriculum: Science* had been constructed, and whether it had been designed to promote actively scientific literacy and the application of this literacy to societal issues. Furthermore, this research aimed to show if Science educators could gain a clear understanding of scientific literacy, its importance in the teaching and learning of Science, and how it could be intentionally taught for to students. This section will detail the results of the macro, meso and micro level analyses of the *Australian Curriculum: Science*, to demonstrate that these aims were realised, and what this means for the position of scientific literacy in the *Australian Curriculum: Science* document.

5.2.1 Macro level analysis findings

Critical discourse analysis includes an investigation of the macro environment of the document, including the social context of how it was developed. For this study, the social context of the development of the *Australian Curriculum: Science* was a review of the Hobart and Adelaide Declarations, the *Statements for Learning*, and the Melbourne Declaration, to determine how scientific literacy had been traditionally positioned in previous policy and curriculum documents. To assist with this, the four key elements for developing scientific literacy were rated on continua, to determine how each policy document positioned the four key elements for developing scientific literacy linguistically.

An analysis of the Hobart Declaration discovered that there seemed to be no clear articulation of what scientific literacy is, or even an acknowledgement of many of what this investigation proposed were the key aspects for developing it. This Declaration did not seem to address the social problem of ambiguity surrounding scientific literacy in curriculum documents. However, the analysis did acknowledge that, due the nature of text production and consumption, and how language and text must be studied in light of the social context in which it was produced (Apple, 2002; Fairclough, 2003), Science curricula of the time were usually content-driven, and did not seem to focus on the development of scientific literacy (Goodrum, et al., 2000). Therefore, in the context of when it was developed, this document would probably not intentionally demonstrate the importance of scientific literacy to Australian Science teachers. Following ten years after the Hobart Declaration, the National Goals for Schooling outlined by the Adelaide Declaration seemed to make no real progress towards the development of scientific literacy in Australian students. The social problem of ambiguity in key educational documents surrounding the importance of scientific literacy and intentional teaching foci, seemed to continue in Australian policy documents that inform curriculum.

When the *Statement of Learning for Science* was analysed, progress was apparently made by the document towards prioritising the development of scientific literacy in Australian students. There seemed to be clarity about some of what this investigation proposes to be the key elements for developing scientific literacy, and some of the uncertainty around scientific literacy seemed to have been addressed. Therefore, it was concluded that due to the macro context in which this document was produced (Fairclough, 2003), when an increase in societal awareness of science and scientific literacy was seen (Goodrum, et al., 2000), the *Statement for Learning for Science* attempted to tackle the social problem of ambiguity in curriculum documents around scientific literacy.

The final document reviewed in the macro level analysis was the Melbourne Declaration; the policy document on which the *Australian Curriculum: Science* is based. Through this analysis it was concluded that, although curriculum documents based on the goals outlined in the Melbourne Declaration could be explicit in their detailing of the importance of some of the key elements for developing scientific literacy (namely Elements One and Two), Elements Three and Four did not seem to be prioritised. This evidence suggested further ambiguity in Australian curriculum documents when discussing scientific literacy, and therefore the Melbourne Declaration was concluded to contribute to the social problem highlighted by this investigation, that is, the uncertainty and lack of clarity around scientific literacy in Australian classrooms.

5.2.2 Meso level analysis findings

A brief outline of the meso level of the document clearly demonstrated the knowledge exchange (Fairclough, 2003) structure that is traditionally inherent in all curriculum documents. On the surface, the document appeared to provide clear information about what is to be taught to Australian Science students, however the discovery of implicit stems throughout the bulk of the document made visible its underlying and more dominant purpose; that of an activity exchange (Fairclough, 2003) document where readers are actually required to act upon the information.

5.2.3 Micro level analysis findings

The critical discourse analysis of the *Australian Curriculum: Science* was organised into the four key elements for developing scientific literacy proposed by this investigation, to determine the linguistic position of scientific literacy in the document. For Key Element One: Scientific knowledge in its multiple representations, the analysis found that the clarity surrounding the mandatory nature of the Content Descriptions could have been improved. Given that it is common for a reader to internalise other discourse moments (beliefs, values) whilst reading a text (Chouliaraki & Fairclough, 1999), the inclusion of the Content Elaborations within the document may be misinterpreted by teachers as being mandatory. Therefore, Science teachers may not readily recognise the choices they can make in regards to the content and contexts in which they can teach. Furthermore, because it is impractical to attempt to determine what scientific content and knowledge students may need in the future, teachers could realign their focus, away from the traditional delivery of scientific content material, and towards a student-centred learning environment (Goodrum, et al., 2000), to determine the current needs of their students. It was concluded that the content descriptors outlined by the *Australian Curriculum: Science* are broad enough to allow teachers and curriculum planners to focus on what they believe is the important knowledge for their students, but that Science teachers and curriculum writers should view the Content Elaborations with limited weight, so that there is greater freedom in ensuring *enough* and relevant scientific content is taught to

Australian students to allow them to engage with the science in society around them.

In regards to Key Element Two: Social relevance, the document was concluded to presented explicit statements as evidence of the importance that science has in society. The opening paragraphs and aims clearly linked the importance of learning science to our personal, social and economic lives, and this relationship between science and society was seemingly placed ‘above’ the learning of scientific content and knowledge in the curriculums aims. In addition, the Science as a Human Endeavour strand incorporated socio-scientific issues, and aimed to ensure students develop as responsible and informed citizens. Therefore, it was concluded that the *Australian Curriculum: Science* excelled at bringing the social relevance of science to the forefront, and as such, the importance of this aspect of developing scientific literacy, demonstrating progress towards overcoming the social problem of scientific literacy being ambiguous in Australian curricula.

For Key Element Three: Cultural and contextual relevance, the curriculum did seem to highlight the need for students to understand the relevance of science to oneself, to culture and to their community, which is an aspect of scientific literacy that is well documented (DeBoer, 2000; Holbrook, 2010; Holbrook & Rannikmae, 2007; Kolstø, 2001; Millar, 2006; Pouliot, et al., 2010; Rennie, et al., 2007; Tomas, et al., 2011; Yore, et al., 2004). This was achieved by providing teachers with the freedom to investigate any social issues that are paramount to their students and their community. However, the reality of teachers recognising and then embracing this freedom by choosing contexts that are most appropriate to their students could be limited. This is because of the social purpose of a curriculum document, and its traditional meso structure as the deliverer of knowledge. Teachers examining this document may not necessarily see that they have freedom to make choices for their students, as they may interpret the text through their own beliefs, values and preconceived ideas (Chouliaraki & Fairclough, 1999) about curricula and the nature of Science teaching and learning. Therefore, it was concluded that the document could be more specific in its instructions to teachers about choosing appropriate contexts.

Finally, in relation to Key Element Four: Critical reflective practice, it was clear that this document only uses a limited form of reflection in the Science Inquiry Skills strand, and this reductive use could inhibit the development of this aspect of scientific literacy. It was concluded that for this element, the document maintains the current social problem of ambiguity about the nature of scientific literacy, because if the term 'reflection' is only used in conjunction with science investigations, teachers and students could misinterpret what they believe to be 'reflecting' in Science, and miss the purpose of critical reflection (Mezirow, 2006; Ryan, 2011) in and about the science they are learning. Students need to critically reflect on their how beliefs and pre-conceived ideas can influence the science learning that occurs in the classroom (Norris & Phillips, 2003), to develop as reflective citizens.

5.3 Limitations

The scope of this research investigation concentrated on analysing Version 3.0 of the *Australian Curriculum: Science* document, published in January 2012. Therefore, one limitation of this study is that it did not include previous or subsequent versions of the document. This was due to the aim of this investigation being very specific to the *Australian Curriculum: Science* document and its portrayal of scientific literacy. Had a previous version of the document been analysed, different conclusions may have been drawn about the position of scientific literacy within the document. Another limitation of the study was that other factors that may have influenced the document's development were not investigated. This included no consultation with developers or writers of the policy or curriculum documents analysed. Therefore, there was no assistance provided by the writers of the documents to explain how they developed the goals for national schooling, the policy and curriculum documents, or the *Australian Curriculum: Science*, or what their perspectives were on scientific literacy and its place in the curriculum. A greater understanding of the documents could have been obtained if contact with the writers had been possible. If further research into the position of scientific literacy in Australian curriculum documents were to be completed, it would be interesting to see how the curriculum writers and developers see the position of scientific literacy in Australian curriculum documents, and whether they see an ambiguity in historical and current curriculum documents about the nature of scientific literacy and how it should be taught in Australian science classrooms.

In addition to these limitations, the scope of this research did not include the opportunity to talk to Australian Science teachers about their interpretation of the position of scientific literacy in the *Australian Curriculum: Science*. Future research in this area could include discussions with Australian Science teachers about how they have interpreted and enacted the document, and how they see the position of scientific literacy in Australian Science classrooms. Finally, the scope of this research did not include the opportunity to discuss scientific literacy with practicing research scientists. It would be beneficial for future research if the practice of current scientists were examined, to determine the nature of scientific literacy in the science community and if the four elements of scientific literacy determined by this investigation represented what occurred in current science practices.

5.4 Recommendations

One of the key research questions to be answered by this investigation was to determine how Science educators could combine the new *Australian Curriculum: Science* and intentional teaching for scientific literacy in a successful manner. In Chapter 4.4, the ways past the problem of social ambiguity surrounding the position of scientific literacy in the curriculum were detailed, including a number of recommendations about how Science teachers can incorporate the four key elements for developing scientific literacy into their science teaching, while maintaining the integrity of the *Australian Curriculum: Science.* Overall, these recommendations are underpinned by the notion that teaching for scientific literacy is central to Science learning, and that it can be the focal point of the three strands of science learning in the *Australian Curriculum: Science*. This was demonstrated in the new graphic representation presented in Figure Nine. In addition to this new focal point of science learning, the recommendations detailed below should be underpinned by professional development, to assist teachers to in developing intentional strategies that promote scientific literacy. The recommendations outlined in Chapter 4.4 can be seen below:

1. This investigation proposed a new graphic representation of how teaching for scientific literacy is central to the three strands of science learning, and should be used as a supplement to the curriculum and to guide professional development about the curriculum;

2. Both existing literature and this investigation recommends that, supported by professional development, school curriculum planners and teachers should view the *Australian Curriculum: Science* with limited weight placed on the Science Understanding Content Elaborations, so that teachers can focus on the mandatory Content Descriptions;

3. This investigation recommends the Science Understanding Content Descriptions be evaluated against the current interests and societal context

of the student, to determine the amount of scientific content that needs to be covered and to ensure Science learning has contextual and social relevance, which is supported by existing literature;

4. As proposed by this investigation, Science teachers should value the Science as a Human Endeavour content description statements provided in the document, which can be achieved by embedding them as part of the curriculum in the initial stages of planning;

5. Derived from existing literature and the conclusions from this investigation, Science teachers are recommended to incorporate societal opinions and ideas into their teaching by using multimodal text types, including media releases, news articles and other mass-media on socio-scientific issues;

6. Both existing literature and this investigation recommend the Science as a Human Endeavour Content Descriptors can be incorporated into assessment items so that Science teachers can highly value the socio-scientific issues introduced;

7. Science teachers are recommended by existing literature to utilise scaffolded comprehension and composition strategies throughout Science lessons, to ensure students are exposed to multi-modal text types and can develop skills to interpret language, construct multi-modal texts, evaluate claims, and construct evidence-based arguments; and

8. The value of critical reflection, as proposed by existing literature, should be recognised by Science teachers, and can be achieved by beginning a concept or topic with reflection questions, discussion and analysis of the students' pre-conceived ideas and beliefs on related socio-scientific issues, so that students can acknowledge that their own beliefs and ideas may influence how science knowledge is learnt, and develop as reflective citizens.

This investigation hopes that by incorporating the eight recommendations detailed above, scientific literacy can come into sharper focus in the pedagogy and curriculum plans of Science teachers in Australia. These eight recommendations address the four key elements for developing scientific literacy proposed by this investigation, and utilise the aspects of the *Australian Curriculum: Science* that may best promote scientific literacy. Therefore, these recommendations fulfil the third research question of this investigation, and give suggestions for how Science teachers in Australia can focus on intentional teaching for scientific literacy whilst maintaining the integrity of the *Australian Curriculum: Science*.

5.5 Significance and further research possibilities

This research has hopefully provided a significant contribution towards intentional teaching for scientific literacy in Australian classrooms. Hackling, Goodrum and Rennie (2001) discovered that historically, Science curricula across States and Territories in Australia did provide future-driven curricula, the goal being the development of scientific literacy for all students. However, there was a gap identified by the literature between the ideal intentions of the curricula and what was seemingly being implemented of it in Science classrooms. This investigation strived to provide strategies for teachers to assist them in bridging this gap that has traditionally existed between Science education and literacy practices in Science classrooms, endeavouring to demonstrate how scientific literacy can be the focal point of Science teaching whilst still preserving the intentions of the curriculum.

The literature has suggested that Science teachers continually believe the Science curricula to be content-heavy, and that if they were to meet the demands of the 'end-of-unit' test, they simply couldn't include targeted scientific literacy activities that took up too much time (Hackling, et al., 2001; Millar, 2006). The four elements developed by this investigation, along with the eight recommendations (derived from both the literature and conclusions drawn by this investigation), will help clarify the nature of scientific literacy, and provide Science teachers with suggestions about how to focus on the mandatory Science Understanding Content Descriptors and incorporate the mandatory Science as a Human Endeavour Content Descriptors in a way that promotes the development of scientific literacy.

There are numerous future research possibilities that stem from this investigation. Firstly, the Four Elements of Scientific Literacy proposed by this investigation can be analysed and revised. This can be conducted following discussions with curriculum writers and classroom teachers, to determine if the elements allowed for a clearer understanding of the nature of scientific literacy, and if they were useful in promoting its intentional teaching. Secondly, as identified in Section 5.3, the limitations of this investigation centre on the inability to conduct discussions with the curriculum writers and developers of the policy and curriculum documents analysed. Future research that incorporated their perspectives on scientific literacy and where they may believe it is positioned within Australian curriculum documents would also prove appealing.

Furthermore, an investigation of how Australian Science teachers have approached the new *Australian Curriculum: Science*, including how they may have interpreted the position of scientific literacy within it and whether this altered how they have enacted the document, could lead to a clearer understanding of the current position of scientific literacy in Australian Science classrooms. In addition to this, future research could also include an investigation of each of the States and Territories implementation plans and how they have approached the change to the *Australian Curriculum: Science*. Each State and Territory may posit their own perspective on the curriculum document, and this may influence how Science teachers interact and respond to the document. Also, an analysis of future results on national and international scientific literacy tests could be undertaken, comparing Australian student results before and after the introduction of the *Australian Curriculum: Science*. Such an analysis could determine if the scientific literacy achievement of Australian students has changed since the introduction of the curriculum.

Finally, clarification can be sought from the science community on how it sees scientific literacy in its current practice. This would be helpful in determining if the scientific literacy defined by this investigation, through the development of the Four Elements of scientific literacy, demonstrates the scientific literacy that is common amongst practicing research scientists. If these four elements do not accurately reflect current understandings of scientific literacy in the science community, future revision and modification of these four elements can be made to incorporate the scientific literacy determined as critical to the science community. This could then be embedded into current Science classrooms, to ensure Science education is developing scientifically literate research scientists for the future.

5.6 Conclusion

With the introduction of the *Australian Curriculum: Science* in 2012, Science educators are seemingly on the verge of a new chapter in Science teaching, with an opportunity to re-evaluate their opinion of scientific literacy and how science knowledge is taught in Australian schools. This investigation aimed to understand where scientific literacy was linguistically positioned within the new *Australian Curriculum: Science*, and if there was the opportunity for Science teachers to gain an awareness of scientific literacy and how to teach for it from the document. Through a critical discourse analysis it was concluded that although the *Australian Curriculum: Science* does seem to promote some aspects of scientific literacy, the social problem of ambiguity within Australian curriculum documents towards the nature of scientific literacy remains. It is hoped that, by utilising the eight recommendations suggested in this investigation, Australian Science teachers might be able to overcome this ambiguity issue and incorporate intentional teaching for scientific literacy into their teaching of the *Australian Curriculum: Science*. Such intentional teaching for scientific literacy could ensure progression towards a future where Australian students develop scientific literacy skills, and can actively engage with the socio-scientific issues presented by this ever-changing world.

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